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Experiments
With Fan Blowers

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EXPERIMENTS WITH FAN BLOWERS

BY


EVERETT SHANNON BONNELL

AND

BRUCE HJALMAR LUNDAHL

THESIS FOR THE DEGREE OF BACHELOR OF SCIENCE
IN MECHANICAL ENGINEERING

IN THE
COLLEGE OF ENGINEERING
OF THE
UNIVERSITY OF ILLINOIS
PRESENTED JUNE, 1905



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EVERETT SHANNON BONNELL and BRUCE HJALMAR LUNDAHL

ENTITLED EXPERIMENTS WITH FAN BLOWERS

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Mechanical Engineering

L. P. Brickmeyer

HEAD OF DEPARTMENT OF Mechanical Engineering

Introduction.

The ordinary centrifugal fan or exhauster consists of a number of blades fixed to arms, revolving on a shaft at high speed. These blades usually are inclosed in a casing which is always of a spiral form. They are adapted to the movement of large volumes of air at pressures varying from one to twenty ounces. With a fan the air is generally discharged into the atmosphere, while with the exhauster it is drawn from the atmosphere.

Classification.—The classification of centrifugal fans is as follows:

Steel Pressure Blowers.

Volume Blowers.

Volume Exhausters.

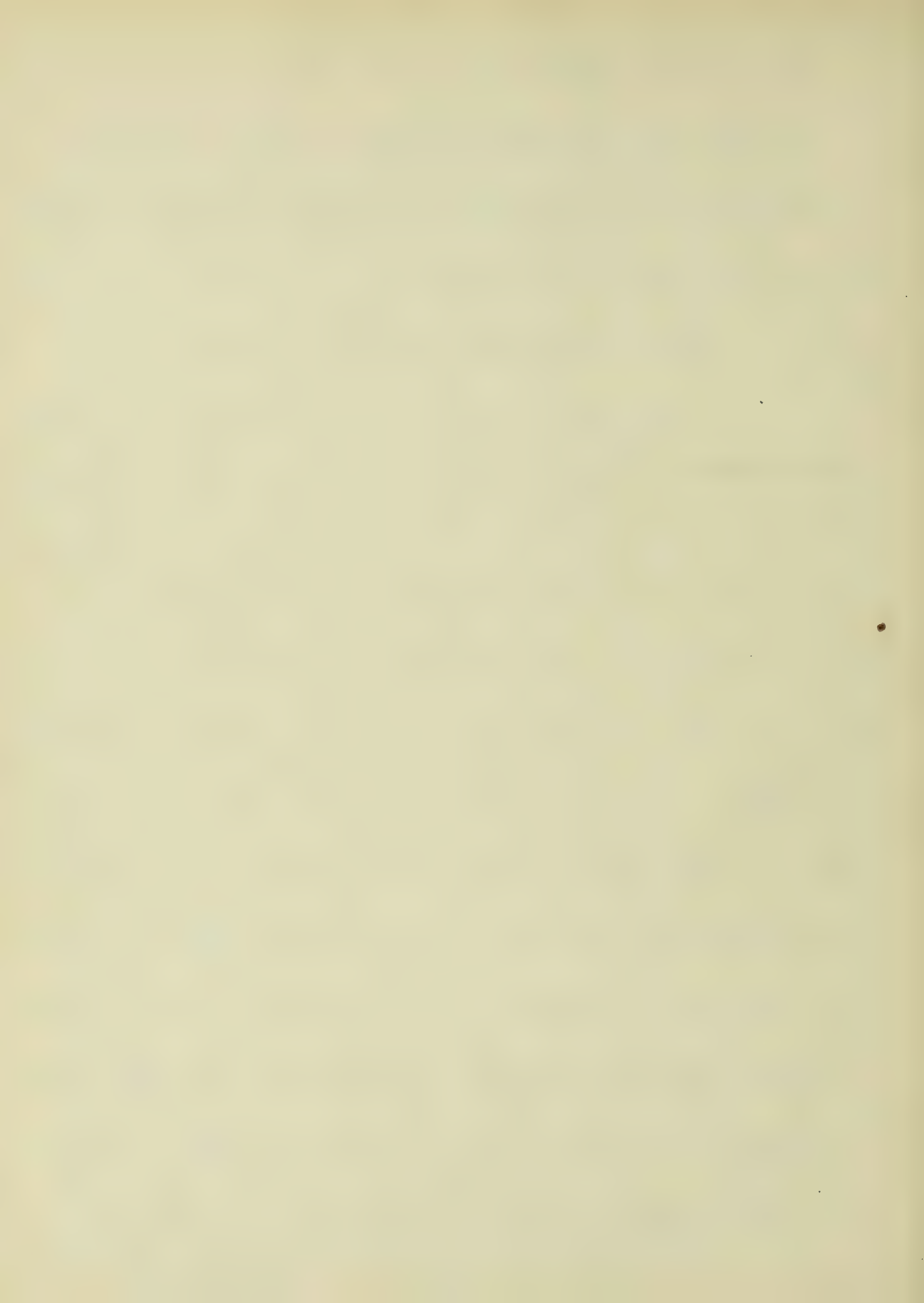
Steel Plate Blowers, and Exhausters.

Sirocco Blowers.

Steel Pressure Blowers.

The steel pressure blower is a fan designed to deliver a small volume of air at a high pressure. They are capable of producing a pressure of as high as twenty ounces, and are adapted for use with cupolas, forges and mechanical stokers.

In order to obtain a small volume of discharge at a high pressure, pressure blowers are made with blast wheels of small widths, as compared to their diameters. The blades, varying in number from



4.

Five to eight, are wider at their inner ends than at their outer circumference, where they are curved backward to allow the air to easily leave the wheel, and to diminish the noise of the fan when running at a high rate of speed. The Sturtevant pressure blowers are built with six blades and twelve or eighteen smaller ones. These small blades are of about half the length as the large ones, between which they are placed. The large blades are all riveted to "T" irons cast on the hub of the blast wheel, while the small blades are riveted to and carried by the conical side plates which ^{extend} ~~ex-~~ from the inlet to the outer

5.
plates
circumference of the wheel. The sides
in turn are carried by the large
blades of the wheel. The casing,
always of a spiral form, is made
of cast iron and usually has its
discharge opening horizontal and
at the bottom. The shaft is of steel
and is hung in two large self-
oil-lubricating bearings, generally of the ring and
wick type. A bearing is placed on
each side of the fan casing and
supported by a pedestal which is
either cast on the casing or bolted
to it. Both one and two driving
pulleys are used. Pressure Blowers
are always mounted on an adjust-
able bed plate but are never directly
connected to the engine, as the

relative speed is too high.

Volume Blowers.

This type of blower is designed and built to discharge a large volume of air against a moderate pressure, two to ten ounces per square inch. In appearance they are very similar to the pressure blowers. The casing, however, is wider and the outlet larger in proportion than in the former. The fan blades in some cases are of an equal width the whole length and are also bent backward as in the pressure blowers. Only one driving pulley is used. Volume blowers also are mounted on adjustable bed plates, and if the relative speed is not to

high may be directly connected to the engine.

Volume Exhausters.

The construction of the general type of volume exhausters is not unlike that of the volume blower, except that there is only one inlet and that the shaft is revolving in two bearings, both of which are placed on the opposite side of the casing from the inlet. The bearings have the driving pulley placed between them and are supported by pedestals in the same manner as in the blower.

Steel Plate Blowers and Exhausters.

This line of blowers and exhausters is built to handle large

volume of air at very low pressures, such as are wanted for ventilating purposes, where this type of fan finds a large field of application. The casing is of steel plate riveted to angle iron for stiffening. There are, as a rule, eight to twelve blades on the blast wheel, which are supported and carried by two or more cast iron spiders. The number of the latter depending upon the size of the fan. The blades are always made straight, seldom if ever being curved backward and then only very slightly right at the tip. The discharge opening may be placed in any

position or direction which is at right angles to the plane of the shaft of the machine. The casing being built in such a manner that it may be revolved around the shaft and fastened at any desired point. A great many of the larger sizes of steel plate blowers and exhausters are fitted with two discharge openings and are run by a direct connected engine.

The Sirocco Blower.

This is a type of fan used very extensively in mining, where it seems to give excellent results. The chief points of its construction are as follows:— The blades

are very numerous, with their radial measurements (relative to the diameter of the fan) very shallow, and their axial measurements very long. Their outer edges are curved forward in the direction of rotation, and the air passages between the blades are usually open at the ends toward the inflowing air. The inlet for admitting air to the fan, and the outlet for its discharge, are approximately of equal diameter to the fan itself. All of these features constitute practically a reversal of previous theory and practice in regard to fan construction, never

the loss, it is claimed that the actual effect of this design is to materially increase the volume of air discharged per revolution. The sirocco fan is well adapted to high speed and therefore to electric driving.

Experiments.

The following series of experiments on Centrifugal Fans and Exhausters was conducted by the writers in the Mechanical Engineering Laboratory of the University of Illinois.

Object.

The object of the tests, made on the fans and exhausters was the determination of their

capacity to move a given volume of air under conditions with respect to the pressure and size of opening of the discharge pipe. Also the determination of the power required for moving a given quantity of air under the conditions named above, and finally, the efficiencies of the fans and exhausters. From the complete tests, as outlined, were determined the most economical conditions under which certain quantities of air could be moved. In order to meet these requirements it was necessary to make accurate measurements of: first, the power required to operate the fan; second,

the volume of air delivered by the fan; third, the pressure produced and fourth, the power required.

Referring to these several requirements, the object may be briefly stated as follows, for each condition.

1. How the quantity of air discharged varies with the speed.
2. How the pressure varies with the speed.
3. How the horse power varies with the speed.

Apparatus.

The arrangement of the apparatus whereby the actual measurements of the horse-power, volume of air discharged, compression and speeds were obtained in each



experiment is shown by plates I. and II. pages 21 and 22 respectively. The fans and exhauster were driven from a counter-shaft, which derived its motion from a twenty five horse-power, horizontal Ball Engine. ^(See page 20) The outlet of the fans and the intake of the exhauster was fitted with a circular galvanized iron pipe twelve feet long, the diameter of which was such as to just fit the opening. A sliding gate (See fig. 2 Plate I.) was attached to the end of the circular pipe, and by means of it the discharge or opening of the fan and intake of the exhauster was varied to suit the different conditions under which

The experiment was run. A Crosby Steam Indicator was used to find the indicated horse power. In all the experiments hand speed counters were used to obtain the R.P.M. of the engine. For obtaining the speeds of the fans and exhauster a calibrated tachometer was used when the arrangement of the fan shaft was such as to permit the tachometer belt to be run upon it, otherwise the speed was obtained with a hand speed counter.

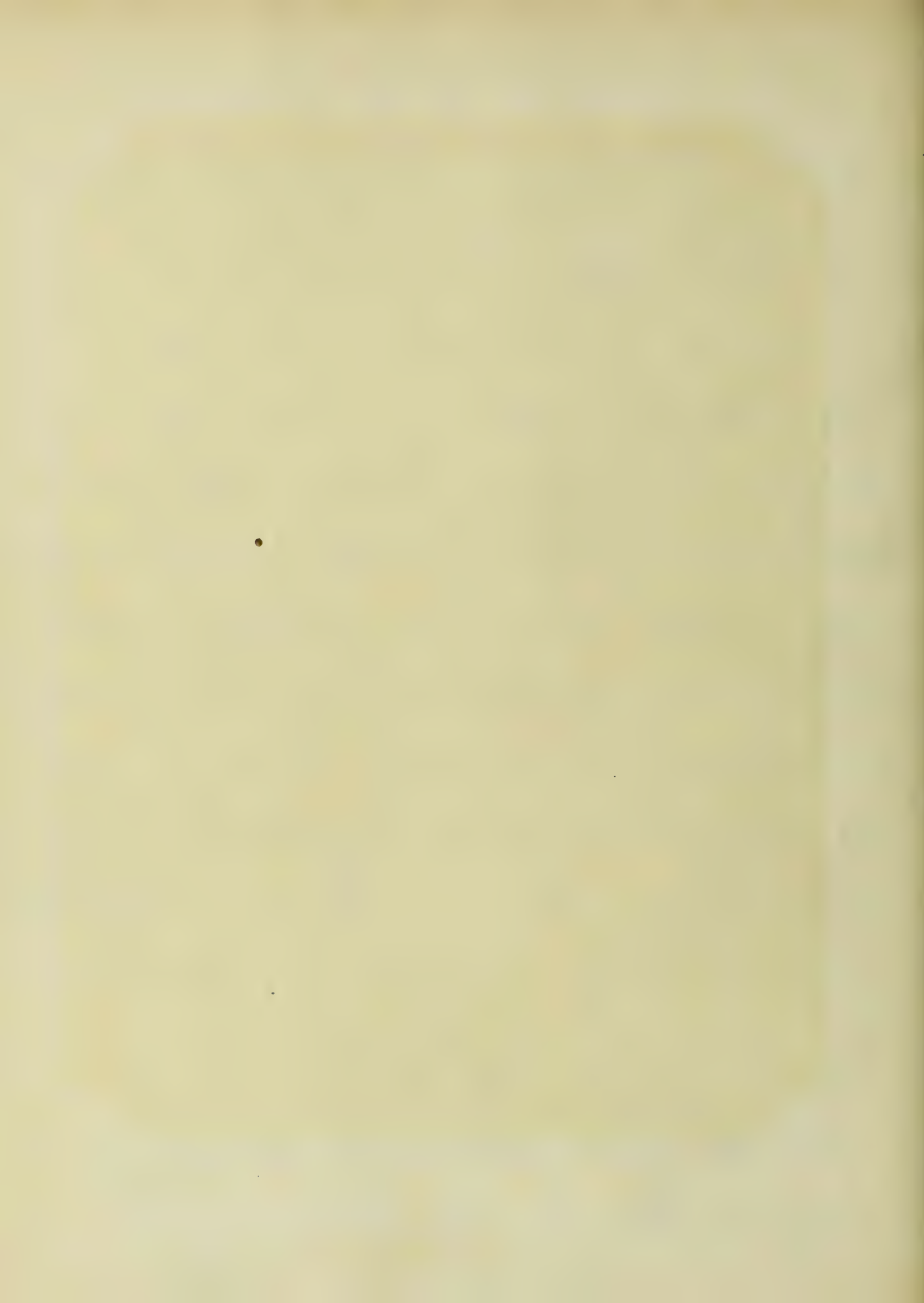
Measurements of the pressure and velocity of the air stream were taken at a section of the pipe five feet from the discharge opening of the fan and seven

seven feet from the intake opening of the exhauster. The pressure of the air was measured with a U shaped gage made from $\frac{1}{4}$ inch glass tubing, and of such a length as would permit the registration of 14" of water. One arm of the gage was open to the atmosphere, while the other was connected by means of rubber tubing to a small pipe, or tip, soldered on to ^{the} side of the delivery tube. The scale used for reading the height of the water column was ruled in ounces and tenths of ounces. For measuring the velocity of the air a combination of the Pitot tube and the pressure gage

was resorted to. Readings were taken at several points in the cross-section of the pipe by means of two velocity tubes, each of which could be traversed over a diameter at right angles to the other. The water gage was of a similar type and construction as was used for the pressure readings, with the exception that its scale was ruled in inches instead of ounces. The velocity tips used (See fig. 5 Plate II, page 22.) consisted of a Pitot tube and a straight tube, having a small circular guide, or side tip, glued on to the end of it. These two tubes were wired together and clamped onto a thin flat stick to give them sufficient strength. The purpose

of the guide was to eliminate the error that presents itself in the measurement of compression, owing to the fact that air flowing across the end of a plain tube causes a large amount of induction; a vacuum being often recorded when a pressure is known to exist. One of the branches, of the U tube, of the velocity gage was connected to the Pitot tube by means of rubber tubing and the other to the tube of the side gage. (See figures 1, 2 and 3 Plate II Page 22.) The pressure in the arm connected to the straight tube, or side tip, will be due to the ^{pression} of the air only, while the pressure in the arm connected with the

Pitot tube will be due to pressure and velocity combined. Hence the reading of the water gage will be the difference of these pressures, which is that due to velocity alone. The velocity tips were held in position by inserting them through suitable openings cut in small boxes which were firmly wired over the holes cut in the delivery tube for inserting the velocity tips. The Pitot tube was placed so that it always faced the current. The U tubes and velocity tips were all made from $\frac{1}{4}$ inch glass tubing, the small circular guides, or side tips, were made of oak, their dimensions being given in fig. 1, Plate II. page 22.

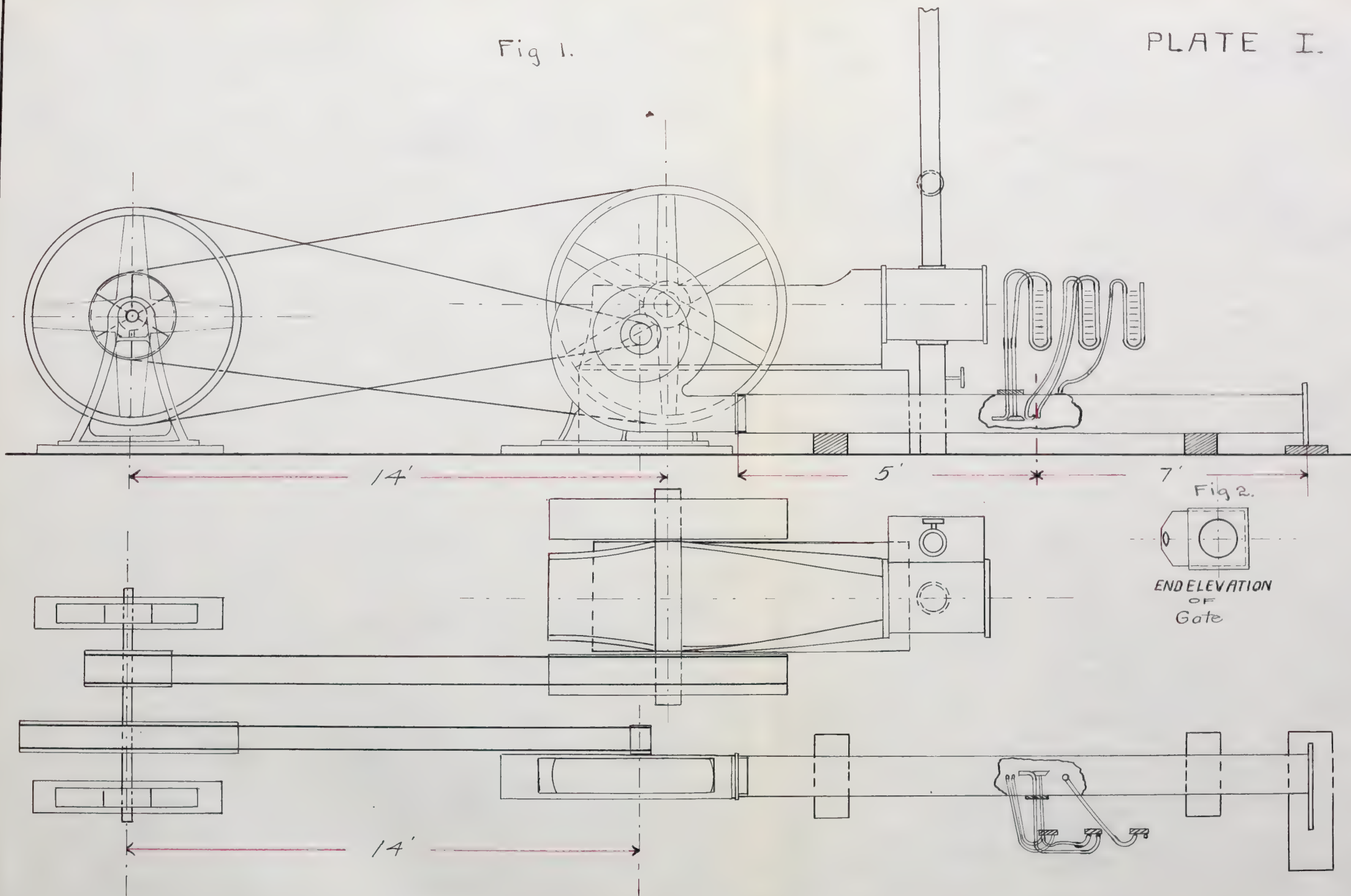




GENERAL ARRANGEMENT
OF
APPARATUS



Fig 1.



FAN-TESTING APPARATUS.

PLATE II.

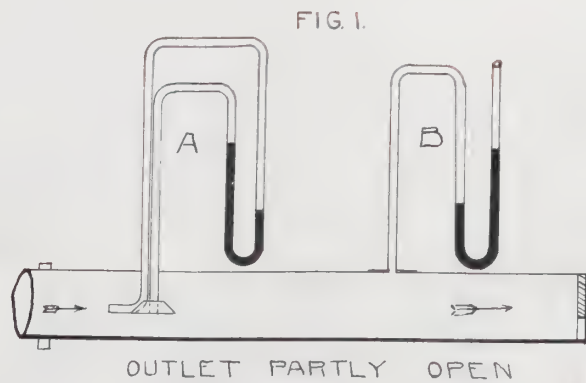


FIG. 1.

OUTLET PARTLY OPEN

FIG. 4.
VELOCITY TIP
SCALE 1/4" = 1"

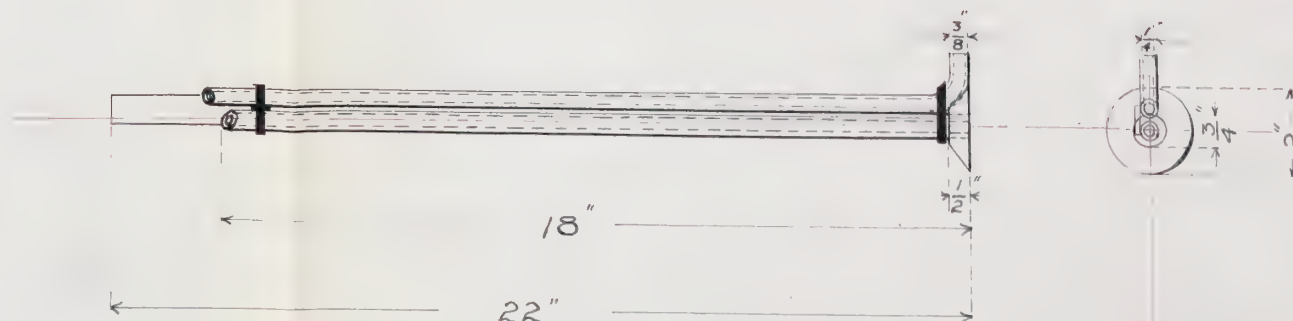
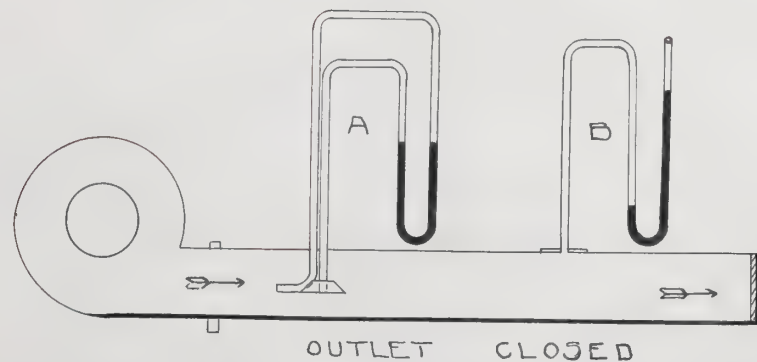


FIG. 2.



OUTLET CLOSED

FIG. 5.
ARRANGEMENT
OF
VELOCITY TIPS
SCALE 1/8" = 1"

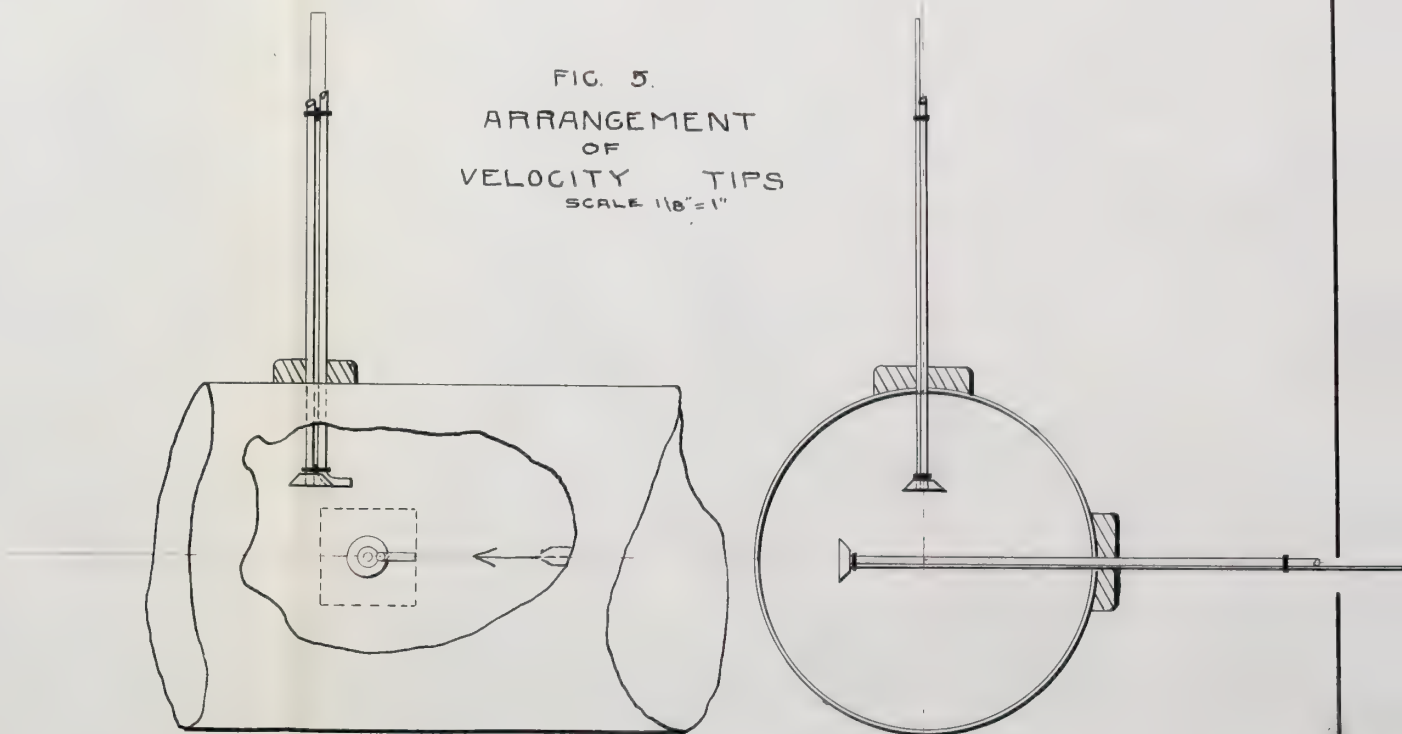
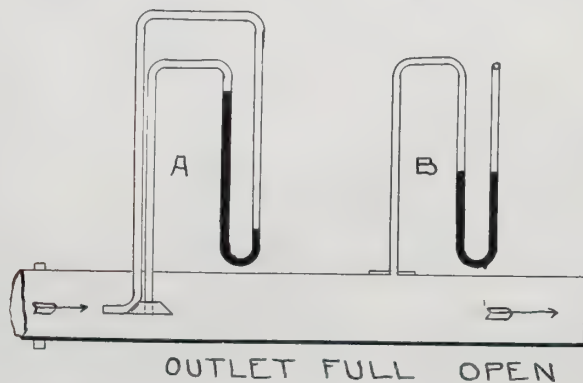


FIG. 3



OUTLET FULL OPEN

A VELOCITY GAGE
B PRESSURE GAGE

APPARATUS FOR MEASURING
PRESSURE AND VELOCITY

Method.

General Outline of Tests: In each set of experiments the quantity of air passed was varied, thus producing a corresponding change in the pressure and power required to drive the fan. This was easily and quickly effected by throttling the flow of air in the delivery tube by means of an air gate placed at the end of the tube. In each experiment, for every speed run, the air was made to pass through this gate successively at full, $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$ and zero ^{gate} opening, except in the case of the No. 1. Sturtevant Blower. Its delivery tube being so small that full $\frac{1}{3}$, $\frac{2}{3}$ and zero gate openings were used.

From eight to twelve speeds, were run for each gate opening, they lying between those for which the fan was designed to run.

Speed.- The governor of the engine used to drive the fan was blocked out and the different speeds were obtained by means of a throttling valve placed in the steam pipe.

Horse-power.- A Crosby Steam Indicator was used for taking indicator cards by means of which the I. H. P. was determined. A friction test was run on the engine and counter shaft and a friction curve was plotted for the various speeds; by the use of it the H. P.

consumed by the engine and counter shaft could be found for any speed. Subtracting this result from the H.P. at the same speed, gave the actual H.P. consumed by the fan alone.

Order of taking readings.—Corresponding to the various speeds, readings were taken for gate openings in the following order: full, $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$ and zero. The gate was first set at full opening and the speed of the fan brought up to the desired point, where it was run for a short time to assure its remaining constant, then the R.P.M. of the fan and engine were taken simultaneously, after which, one

man took the indicator card while the other read the pressure and velocity gauges as quickly as possible: these readings were checked by reading the gauges twice. The remaining gate openings were then taken in the order named. The velocity gauges were marked at points corresponding to the distances to which they would have to be inserted into the delivery tube, to correspond to the centers of the equal areas into which the cross section of the tube was supposed to be divided, in order that they might be the more quickly manipulated and read. The horizontal ^{velocity} gauge was always read first

27

then the vertical velocity gage after which the pressure was noted.

Temperature and Barometer readings. - The average temperature was determined by placing a thermometer at the discharge opening and taking a reading every thirty minutes. The barometer readings recorded are the averages for the days on which the tests were run.

Calculations.

Actual Horse-power to Drive the Fan. - The measurement of the total horse-power required to operate the fan was obtained from indicator diagrams taken as previously explained. This indicated horse power, however, shows not the power applied to the fan,



but the power applied to the piston of the engine. To find the actual H. P. used to drive the fan, this I. H. P. was decreased by the amount of the power absorbed by the friction of the engine and counter shaft. A friction test was run on the engine and counter shaft at a wide range of speeds and the results plotted. From the curve this obtained could be determined the friction H. P. for any speed. Subtracting this result from the I. H. P. taken at the same speed the actual H. P. to drive the fan was obtained.

Pressure.— The pressure was read directly from the gage in ounces,

(see description of pressure gage, page)
 thus eliminating the calculation of
 each pressure separately, if the read-
 ings had been taken in inches of
 water. The calculation for reducing
 inches of water to ounces of pressure,
 in order to rule the scale in ounces
 was made as follows:—

1 lb.-press. corresponds to 2.304 ft. of water.

16 oz " " " 27.648 in. " "

1 oz " " " 1.727 " " "

This length in inches (1.727") correspond-
 ing to one ounce of pressure, was
 subdivided into tenths and the
 scale ruled accordingly.

Velocity.— The calculation of the
 velocity was made according to
 the formula deduced by Heeren

and Gillist. in Vol. 123, of the P. E. C. E. Suppose the air to be flowing directly against the mouth of a tube which is connected to a gauge for the purpose of measuring the pressure produced by this velocity. The pressure h , in feet of air due to a velocity of v ft. per sec. is $h = \frac{v^2}{2g}$ (1).

If h be measured in inches of water, as it would be measured in practice, regard must be had to the relative densities of air and water at the time of the experiment.

Let h = pressure measured as a column of air in feet.

Let i = the corresponding pressure measured in inches of water.

T = the absolute temperature of the air in degrees F. a. h.

h = height of the barometer in inches of mercury.

Then PV being equal to $53.2T$ for one pound of air, when P , the pressure of the atmosphere, would be measured by a barometer, the following numerical relation is found between h and i :—

$$h = 3.91 \frac{i \times T}{h_0} \quad (2).$$

H.P. of fan = $\frac{V \times i}{6.352} \quad (3).$ This equation is deduced under the heading of theoretical horse-power.

Substituting the value h in equation

$$(3) \quad i = \frac{V^2 h_0}{251.7T} \quad (4)$$

This formula gives the reading of the water-gage due to velocity V .


for any given atmospheric condition of barometer and temperature.

When $T = 60^{\circ}F$ and $h_b = 30''$ mercury

$$i = \frac{V^2}{4370} \text{ or } V = \sqrt{i \times 4370}.$$

In applying this formula to obtain our results the average values of the temperature, barometer and i readings were used.

Volume. — The volume of air delivered was found by obtaining the average velocity of the air in the discharge pipe and multiplying it by the area in sq. ft. of the pipe. This average velocity was obtained as follows: the discharge pipe, in each case, was divided into a number of equal areas and four readings

taken in each area (as at a, b, c and d ). The mean of these readings was taken as the velocity of that area. The velocities of the remaining areas were found in the same manner and then the average of the velocities of all the areas was taken as the correct velocity of the air in the delivery tube. With the average velocity known the volume in cu. ft. per sec. was computed by multiplying the velocity in ft. per sec. by ^{of a cross section} the area of the discharge pipe in sq. ft. The amount of air discharged per H.P. per sec. was obtained by dividing the discharge in cu. ft. per sec. by the H.P.

required to drive the fan at that velocity.

Theoretical Horse Power: The work done by the fan in cu. ft. ft. per lb. of air entering the fan is: Volume of air in cu. ft. per lb. \times the increase in pressure in lbs. per sq. foot, and where,

V = Vol. of air entering fan in cu. ft. per min.
 i = Dist. in inches of water. A pressure of 1 inch of water being equivalent to 5.2 lbs. pr. sq. ft.

$$\text{Theoretical H.P.} = \frac{V \times 5.2 i}{33000} = \frac{V \times i}{6352}$$

Since 1 ounce of pressure = 9 lbs. pr. sq. ft. the above formula reduces to the form,

$$\text{Theoretical H.P.} = \frac{V \times .07}{3666.66}$$

Efficiency:— The efficiency of

the fan and exhauster was found
by dividing the theoretical H.P. by
the actual H.P. required to drive
the fan.

EXPERIMENT NO. 1

Buffalo Volume Blower No. 8.

See Plate 21. ^{p. 40.} The general structural details of this blower are as follows. To the solid (cast iron) outer peripheral shell, which carries likewise the discharge orifice, are securely bolted two side plates, in which are formed the inlets. The pedestals carrying the standard oil ring bearings are bolted to these side plates. The blower is built with only one driving pulley. Its blast wheel is built with five wrought iron, radial spokes, bent backward at their outer ends, each carrying a blade which continues this backward curvature of the spokes to

to their outer circumstances. Thus making a total backward curvature of 3 inches. Conical side plates are riveted to the spokes and extend entirely around the wheel thus making it very rigid.

Table of Dimensions:—

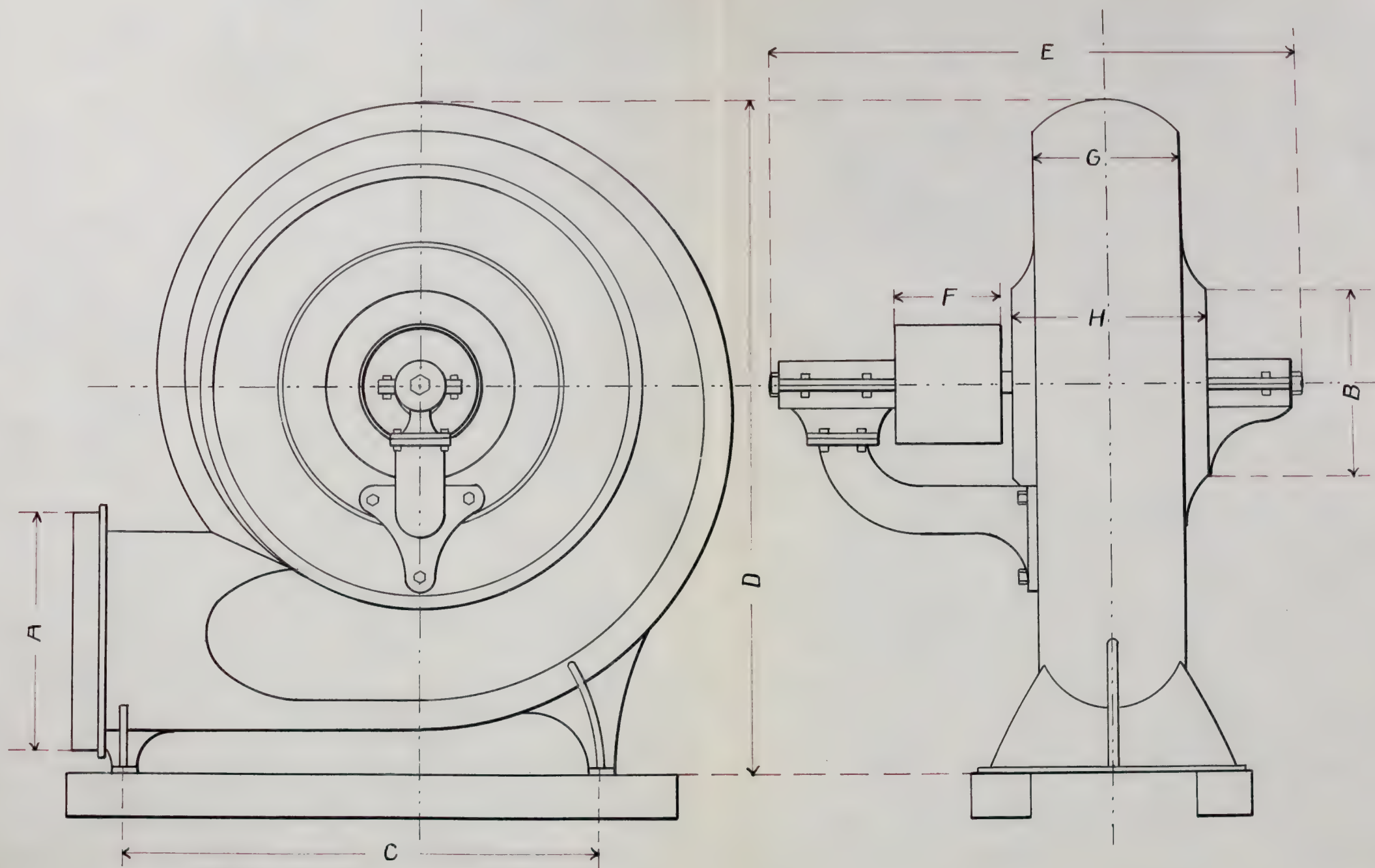
Height Total	48"
Length " "	47.5"
Width " "	10"
Diam. of Pulley	8.5"
Width " "	7.5"
Diam. of Blast Wheel	28"
Width " " " "	11"
No. of Blades	5
Size " " "	11" x 4"
Area of " "	88 sq. in.
Diam. Bullet (outside of flange)	16.5"

diam. Outlet (inside of pipe flange)	13"
Area " " "	132.7 sq. in.
diam. & Inlet (pulley side)	13.5"
Area " " " " "	86.4 sq. in.
The area of the pulley was subtracted as it obstructed the opening.	
diam. & Inlet (opposite side)	13.5"
Area " " "	114 sq. in.
Ratio $\frac{\text{Area of Inlet}}{\text{Area of Outlet}} =$	1.56
diam. of Shaft.	1.75"
Length of Bearings	9"

Temperature and Barometer Readings

Barometer (correction)	29.2"
Temperature	80.8°F

PLATE III.
BUFFALO VOLUME BLOWER NO 8.

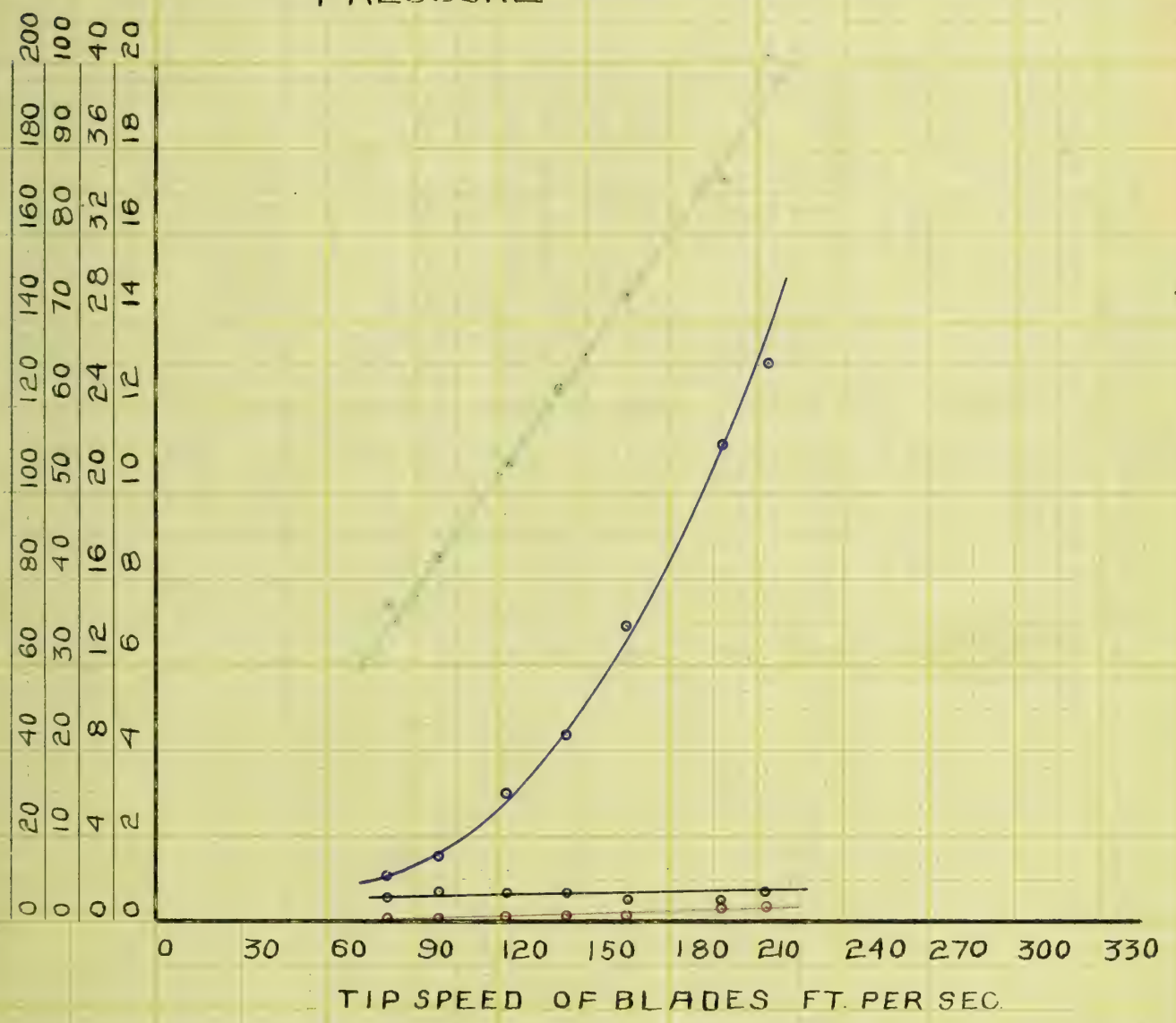


[illegible]

CHARACTERISTIC CURVES FOR BUFFALO BLOWER TABLE I.

VOL. CU. FT. PER SEC.
EFFICIENCY
H.P.
OZ. PRESSURE

VOLUME
EFFICIENCY
H.P.
PRESSURE



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CHARACTERISTIC CURVES FOR BUFFALO BLOWER TABLE 2.

VOL. CU. FT. PER SEC.
EFFICIENCY
H.P.
OZ. PRESSURE

200 180 160 140 120 100 80 60 40 20 0
100 90 80 70 60 50 40 30 20 10 0
40 36 32 28 24 20 16 12 8 4 0
20 18 16 14 12 10 8 6 4 2 0

VOLUME
EFFICIENCY
H.P.
PRESSURE

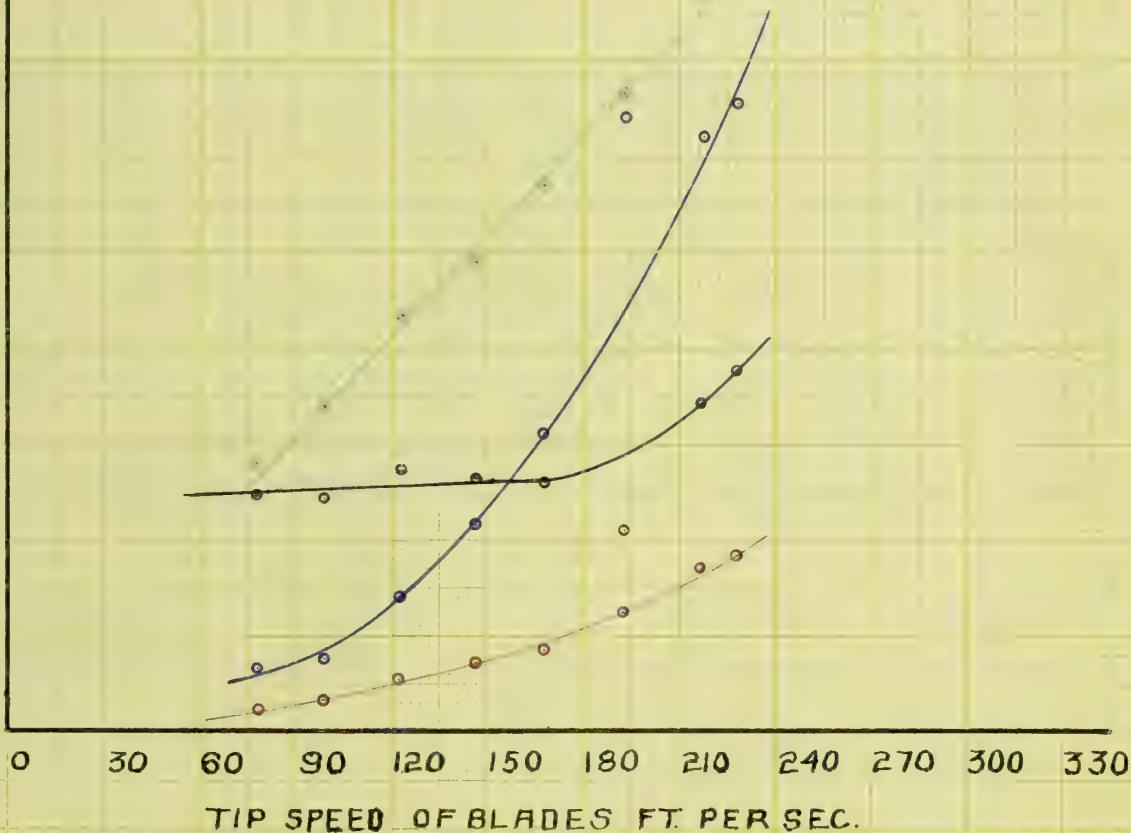


TABLE 3.

DATA AND RESULTS
FOR
BUFFALO BLOWER NO 8.

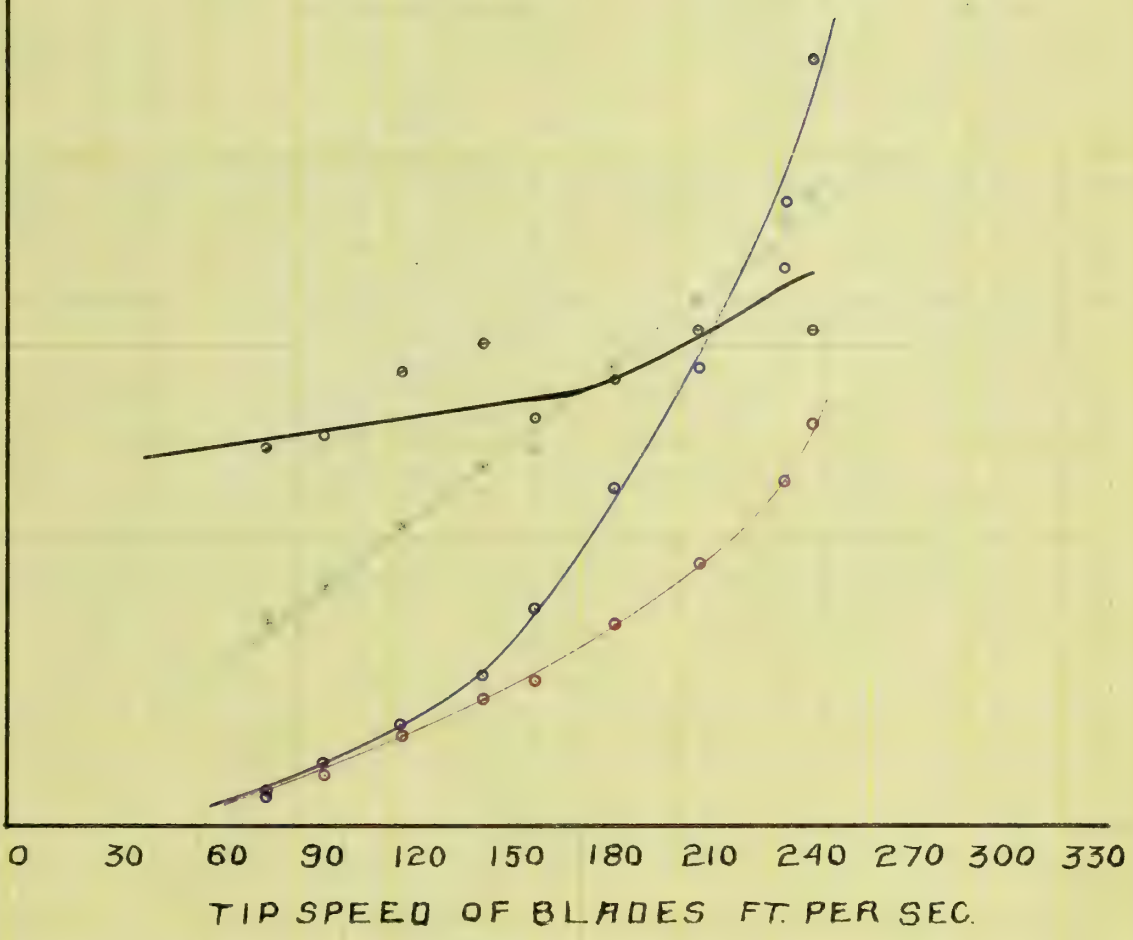
1/2 OPENING
OF
DISCHARGE

[illegible]

CHARACTERISTIC CURVES FOR BUFFALO BLOWER TABLE 3.

VOL. CU. FT. PER SEC.		200	180	160	140	120	100	80	60	40	20	0
EFFICIENCY		100	90	80	70	60	50	40	30	20	10	0
H.P.		40	36	32	28	24	20	16	12	8	4	0
OZ. PRESSURE		20	18	16	14	12	10	8	6	4	2	0

VOLUME
EFFICIENCY
H.P.
PRESSURE



[illegible]

CHARACTERISTIC CURVES FOR BUFFALO BLOWER TABLE 4.

VOL. CU. FT. PER SEC.
EFFICIENCY
H. P.
OZ. PRESSURE.

200
100
40
20
180
90
36
16
140
70
28
12
100
50
20
80
40
16
60
30
12
40
8
4
20
2
0
0
0
0

VOLUME
EFFICIENCY
H. P.
PRESSURE

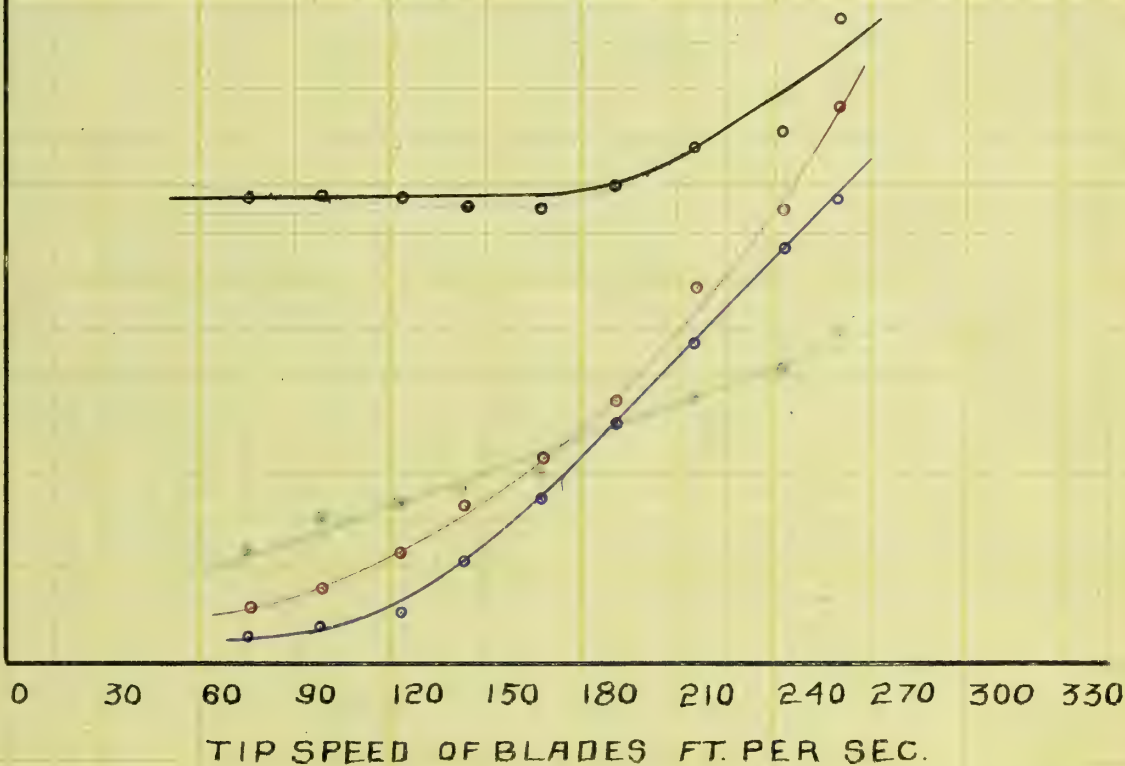


TABLE 5.

DATA AND RESULTS
FOR
BUFFALO BLOWER NO 8.

O OPENING.
OF
DISCHARGE

[illegible]

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EXPERIMENT NO. 2

Buffalo Pressure Blower No. 7.

The general appearance of this blower is the same as that of No. 8 (See Plate VII, page 40.) except that it has two driving pulleys and that its blast wheel is built with ten blades, five large and five small ones. The small blades are about one third the size of the large ones, between which they are placed, being riveted to the outer conical rim of the blast wheel.

Table of Dimensions:—

Height Total	33.5"
Length " "	34"
Width " "	30.75"
Diam. of Pulleys	5"

Face of Pulleys		4 $\frac{3}{8}$ "
Diam. of Shaft		1 $\frac{3}{8}$ "
Diam. of Blast Wheel		17 $\frac{1}{4}$ "
Width of " " at	{ outer	5 $\frac{3}{8}$ "
	{ Circ.	2 $\frac{1}{4}$ "
No. of Blades	{ Long	5
	{ Short	5
Area of Blades		11.7 sq. in.
Diam. of Discharge Opening		6 $\frac{7}{8}$ "
Area " " " "		37 $\frac{1}{8}$ sq. in.
Diam. of Inlets		9"
Area " " "		127.24 sq. in.
Ratio $\frac{\text{Inlet Area}}{\text{Outlet Area}}$		2.3

The area of the pulleys were subtracted from the inlet area as they obstructed the openings.

Temperature and Barometer Readings.

Barometer (average)	29.3"
Temperature " "	79 $\frac{1}{4}$ ° F.

CHARACTERISTIC CURVES FOR BUFFALO BLOWER TABLE 6.

0	20	40	60	80	100	120	140	160	180	200	VOL. CU. FT. PER SEC.
0	10	20	30	40	50	60	70	80	90	100	EFFICIENCY
0	4	8	12	16	20	24	28	32	36	40	H.P.
0	2	4	6	8	10	12	14	16	18	20	OZ. PRESSURE

VOLUME
EFFICIENCY
H.P.
PRESSURE

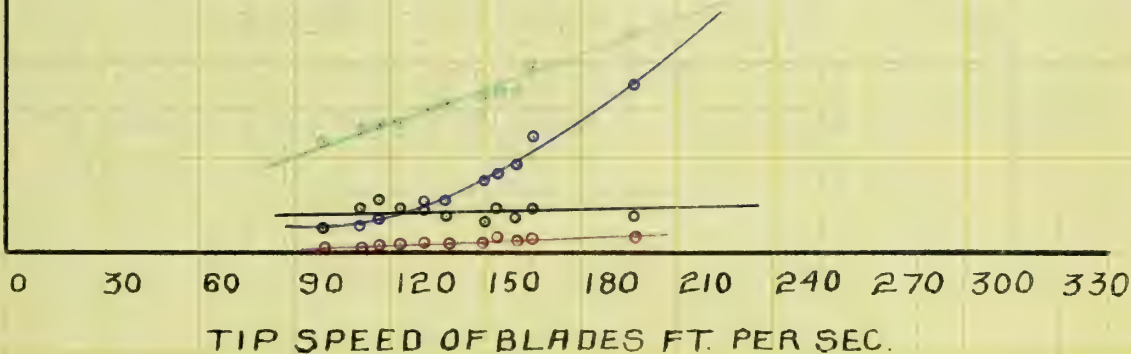
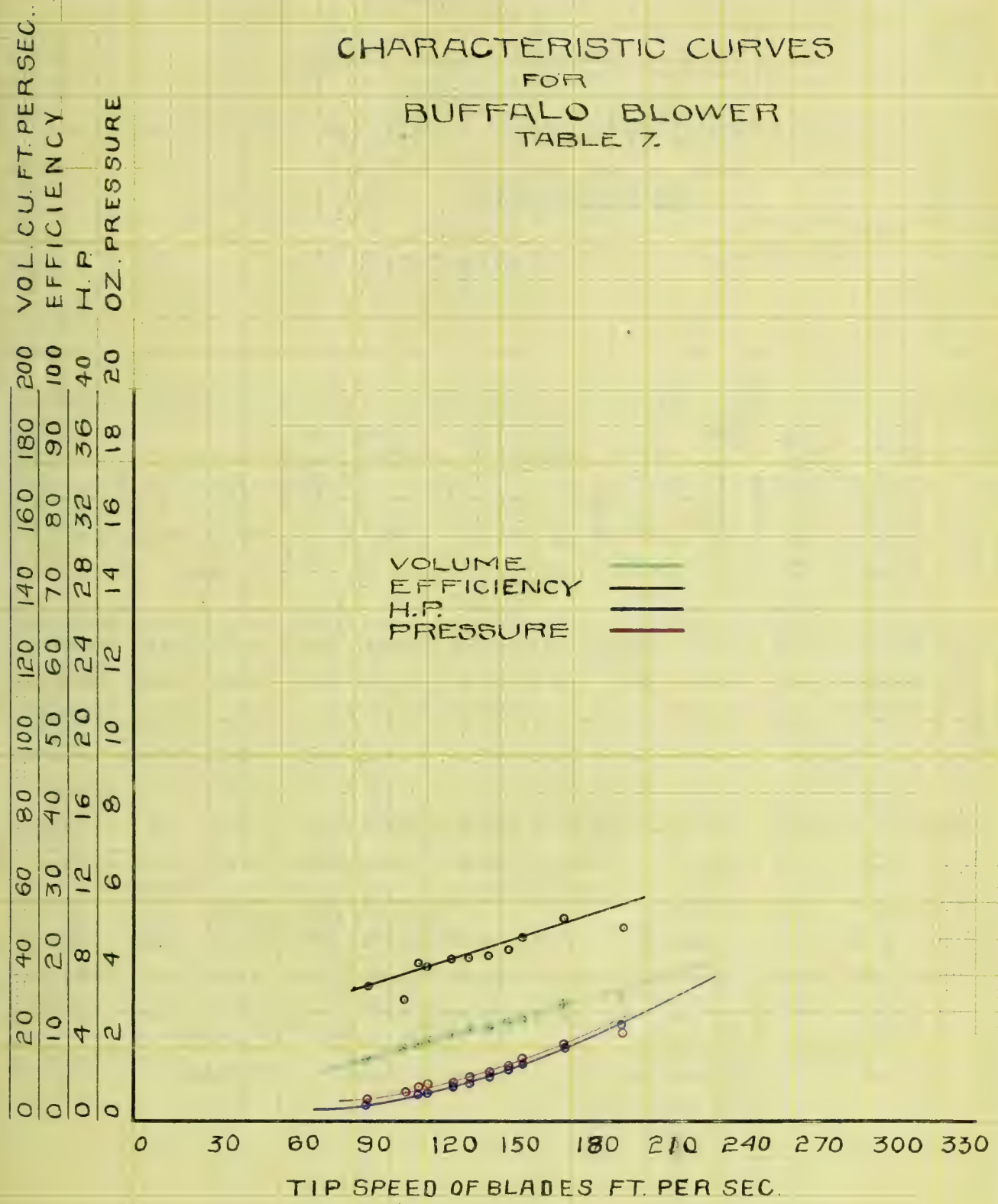


TABLE 7.

DATA AND RESULTS
FOR
BUFFALO BLOWER NO 7.
3/4 OPENING
OF
DISCHARGE

[illegible]

CHARACTERISTIC CURVES FOR BUFFALO BLOWER TABLE 7.

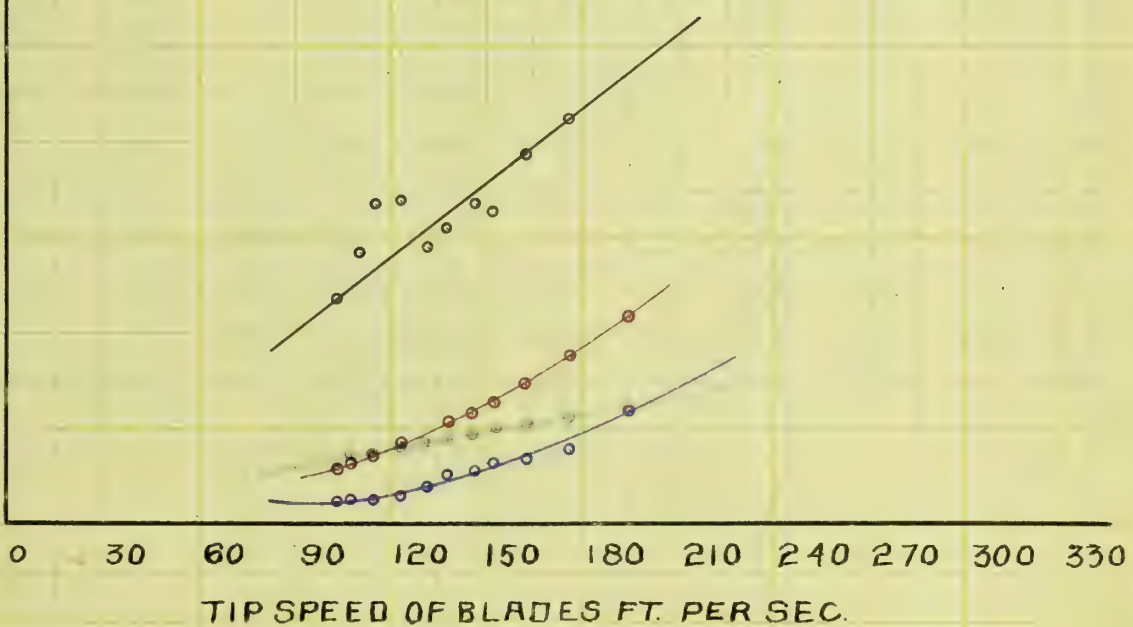


CHARACTERISTIC CURVES FOR BUFFALO BLOWER TABLE 8.

VOL. CU. FT. PER SEC.
EFFICIENCY
H.P.
OZ. PRESSURE

0	20	40	60	80	100	120	140	160	180	200
0	10	20	30	40	50	60	70	80	90	100
0	4	8	12	16	20	24	28	32	36	40
0	2	4	6	8	10	12	14	16	18	20

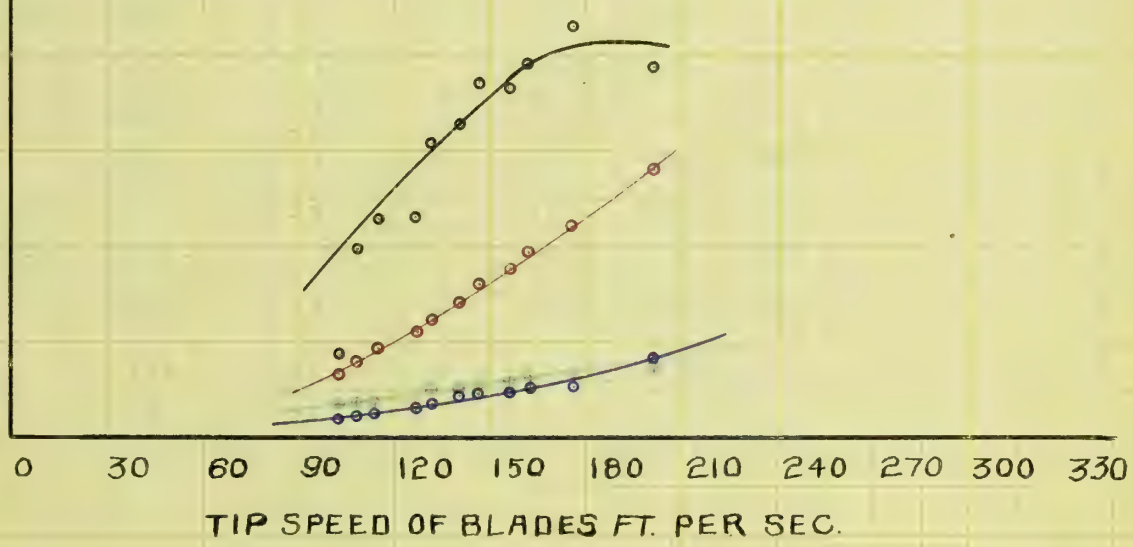
VOLUME
EFFICIENCY
H.P.
PRESSURE



CHARACTERISTIC CURVES
FOR
BUFFALO BLOWER
TABLE 9.

VOL CU. FT. PER SEC.									
EFFICIENCY									
H.P.									
OZ. PRESSURE									
200	180	160	140	120	100	80	60	40	20
100	90	80	70	60	50	40	30	20	10
40	36	32	28	24	20	16	12	8	4
20	18	16	14	12	10	8	6	4	2

VOLUME
EFFICIENCY
H.P.
PRESSURE



1. The first part of the paper is devoted to a general discussion of the problem.

2. The second part is devoted to a detailed analysis of the results.

3. The third part is devoted to a discussion of the conclusions.

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100

4. The fourth part is devoted to a discussion of the results.

TABLE 10.

DATA AND RESULTS
FOR
BUFFALO BLOWER NO 7.

O OPENING
OF
DISCHARGE

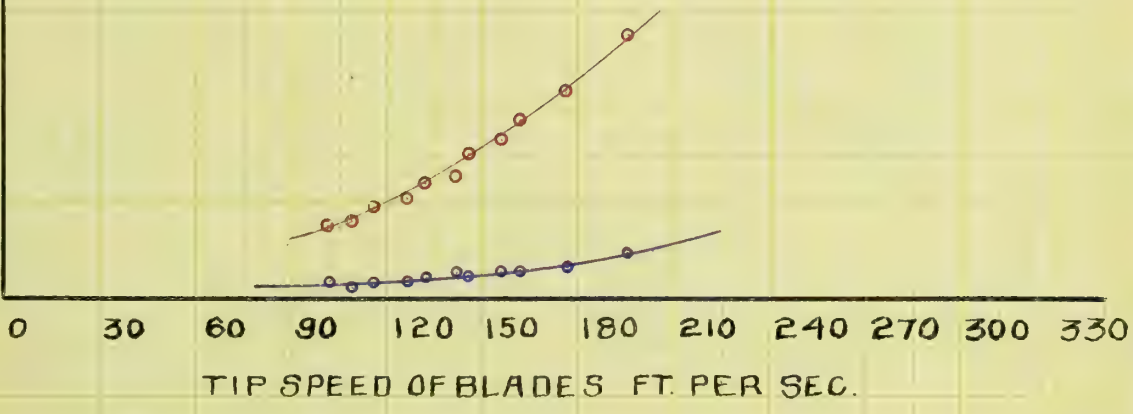
[illegible]

CHARACTERISTIC CURVES FOR BUFFALO BLOWER TABLE 10

VOL. CU. FT. PER SEC.
EFFICIENCY
H.P.
OZ. PRESSURE.

0	20	40	60	80	100	120	140	160	180	200
0	10	20	30	40	50	60	70	80	90	100
0	4	8	12	16	20	24	28	32	36	40
0	2	4	6	8	10	12	14	16	18	20

H.P.
PRESSURE



1911

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EXPERIMENT NO. 3

Buffalo Column Blower No 4.

The appearance and details of this blower are substantially the same as those of Column Blower No 3 (See Plate 11 Page 40, and description of No. 3 page 37.) The only difference in the two blowers is that of size.

Table of Dimensions:-

Height Total	38"
Length " "	27½"
Width " "	29⅜"
Diam. of Pulley	5"
Face " " "	4"
Diam. of Shaft	1¼"
Diam. of Blast Wheel	16¼"
Width " " " at	<div style="display: flex; align-items: center;"> <div style="font-size: 3em; margin-right: 10px;">{</div> <div> <div style="margin-bottom: 10px;">Circ. 4¼"</div> <div>Center 6⅞"</div> </div> </div>

No of Blades	5
Size " " "	
Area " " "	19.3 sq. in.
Diam. of Discharge Opening	8 1/2"
Area " " " " "	56 3/4 sq. in.
Diam. " Inlets (two)	8"
Area " " "	100.5 sq. in.
Ratio $\frac{\text{Inlet Area}}{\text{Outlet Area}} =$	1.2

Temperature and Barometer Readings

Barometer (corrected)	29.76"
Temperature " "	76.54° F.

TABLE II.

DATA AND RESULTS
FOR
BUFFALO BLOWER NO 4.
FULL OPENING
OF
DISCHARGE

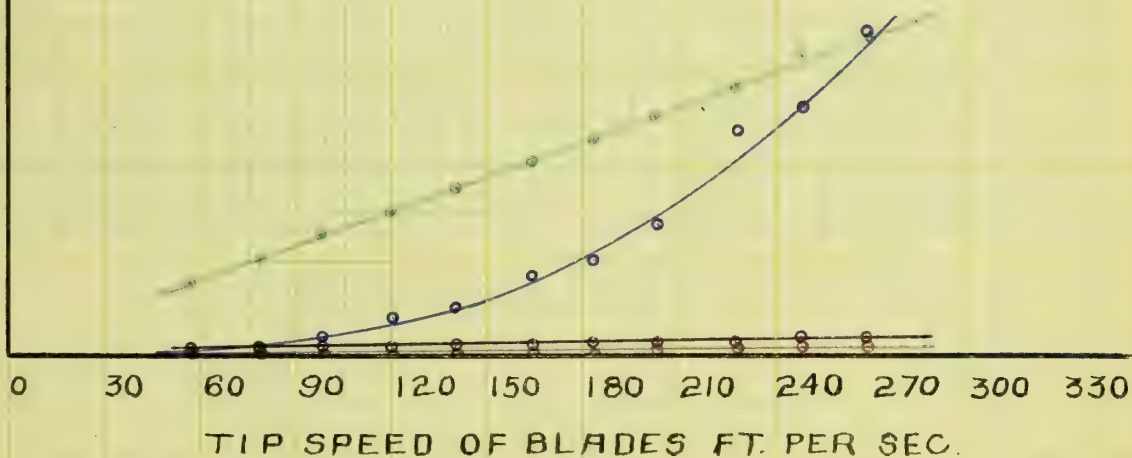
R.P.M. FAN	R.P.M. ENG.	PRESSURE OZ. PER. SQ. IN.	VEL. HEAD IN. WATER	VEL. OF AIR FT. PER. SEC.	AIR. DISCH. CU. FT. PER. SEC.	VEL. FAN TIPS FT. PER. SEC.	H.P. TOTAL	H.P. TO DRIVE FAN	H.P. THEORETICAL	CU. FT. AIR DISCH. PER. H.P. PER. SEC.	EFF. O/O.
822	52	.02	.28	35.7	15.4	58	.55	.39	.004	39.4	1.0
1116	70	.02	.45	45.8	19.7	79	.88	.53	.006	35.4	1.1
1394	87	.02	.75	58.5	25.2	99	1.29	.85	.008	30.0	.9
1718	108	.03	1.07	69.8	29.9	121	2.60	1.96	.015	15.2	.8
1988	125	.04	1.46	81.5	34.8	141	2.90	2.09	.023	16.2	1.1
2320	149	.05	1.97	94.7	40.4	165	4.24	3.23	.034	12.8	1.1
2592	164	.07	2.46	106.0	45.6	184	5.35	4.02	.052	11.3	1.3
2870	187	.10	3.06	118.0	50.7	203	7.67	5.95	.085	8.5	1.4
3234	204	.13	3.94	133.8	57.2	229	10.77	8.69	.122	6.6	1.4
3502	223	.20	4.74	147.0	63.2	248	12.91	10.41	.210	6.0	2.0
3792	242	.21	5.40	157.0	67.5	269	16.63	13.68	.233	4.9	1.7

CHARACTERISTIC CURVES FOR BUFFALO BLOWER TABLE II.

VOL. CU. FT. PER SEC.
EFFICIENCY
H.P.
OZ. PRESSURE.

200
180
160
140
120
100
80
60
40
20
0
200
180
160
140
120
100
80
60
40
20
0
20
10
4
0

VOLUME
EFFICIENCY
H.P.
PRESSURE



107

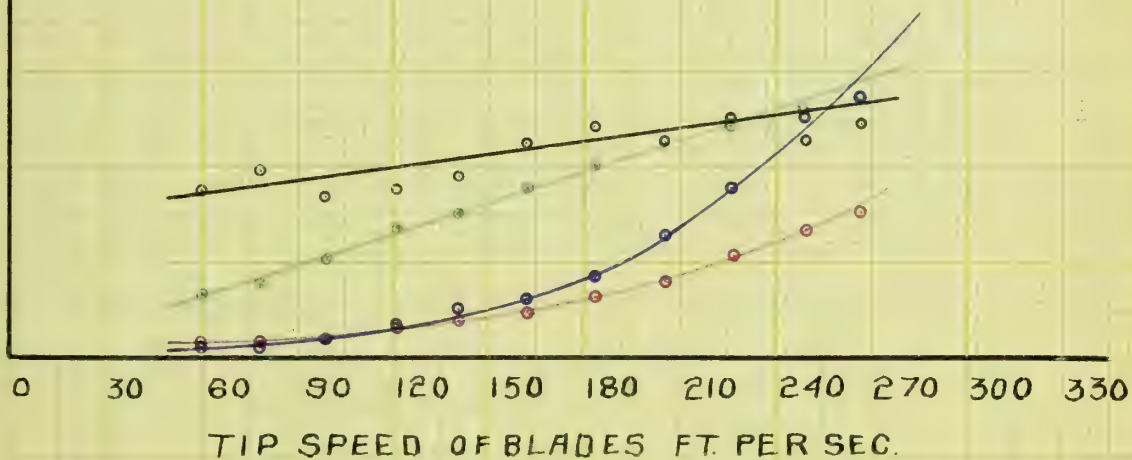
[illegible]

CHARACTERISTIC CURVES FOR BUFFALO BLOWER TABLE 12.

VOL. CU. FT. PER SEC.
EFFICIENCY
H.P.
OZ. PRESSURE

0	20	40	60	80	100	120	140	160	180	200
0	10	20	30	40	50	60	70	80	90	100
0	4	8	12	16	20	24	28	32	36	40
0	2	4	6	8	10	12	14	16	18	20

VOLUME
EFFICIENCY
H.P.
PRESSURE

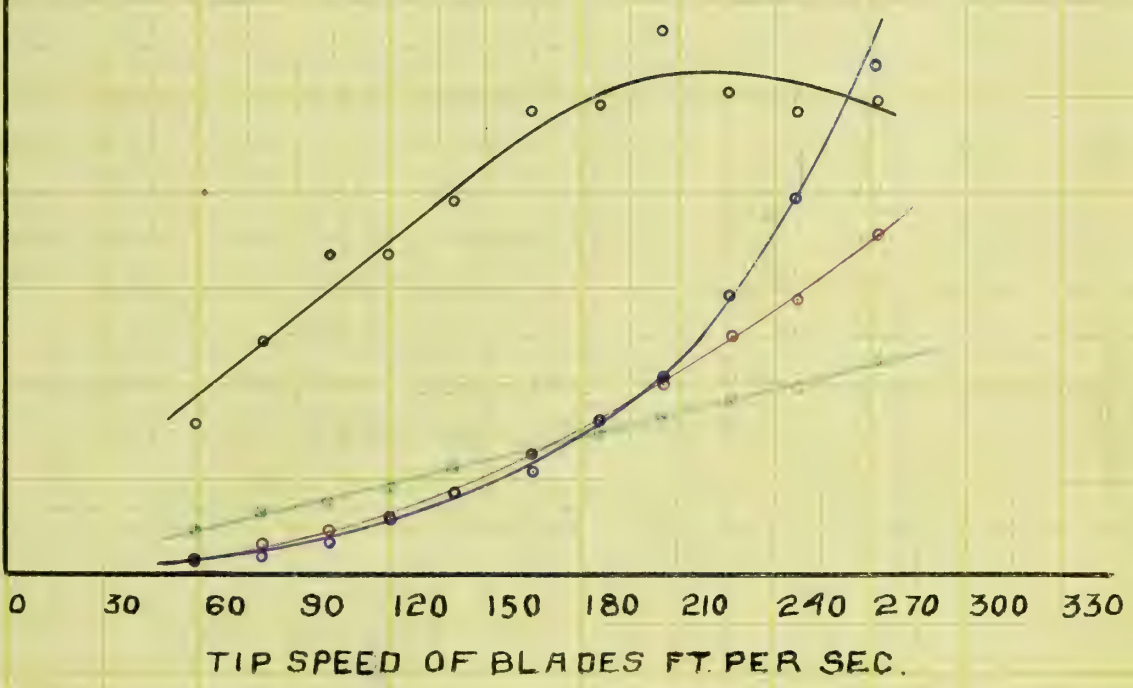


CHARACTERISTIC CURVES FOR BUFFALO BLOWER TABLE 13.

VOL. CU. FT. PER SEC.
EFFICIENCY
H.P.
OZ. PRESSURE

0	20	40	60	80	100	120	140	160	180	200
0	10	20	30	40	50	60	70	80	90	100
0	4	8	12	16	20	24	28	32	36	40
0	2	4	6	8	10	12	14	16	18	20

VOLUME
EFFICIENCY
H.P.
PRESSURE



CHARACTERISTIC CURVES FOR BUFFALO BLOWER TABLE 14

VOL. CU. FT. PER SEC.
EFFICIENCY
H.P.
OZ. PRESSURE

200
100
40
20

180
90
36
18

160
80
32
16

140
70
28
14

120
60
24
12

100
50
20
10

80
40
16
8

60
30
12
6

40
20
8
4

20
10
4
2

0
0
0
0

VOLUME
EFFICIENCY
H.P.
PRESSURE

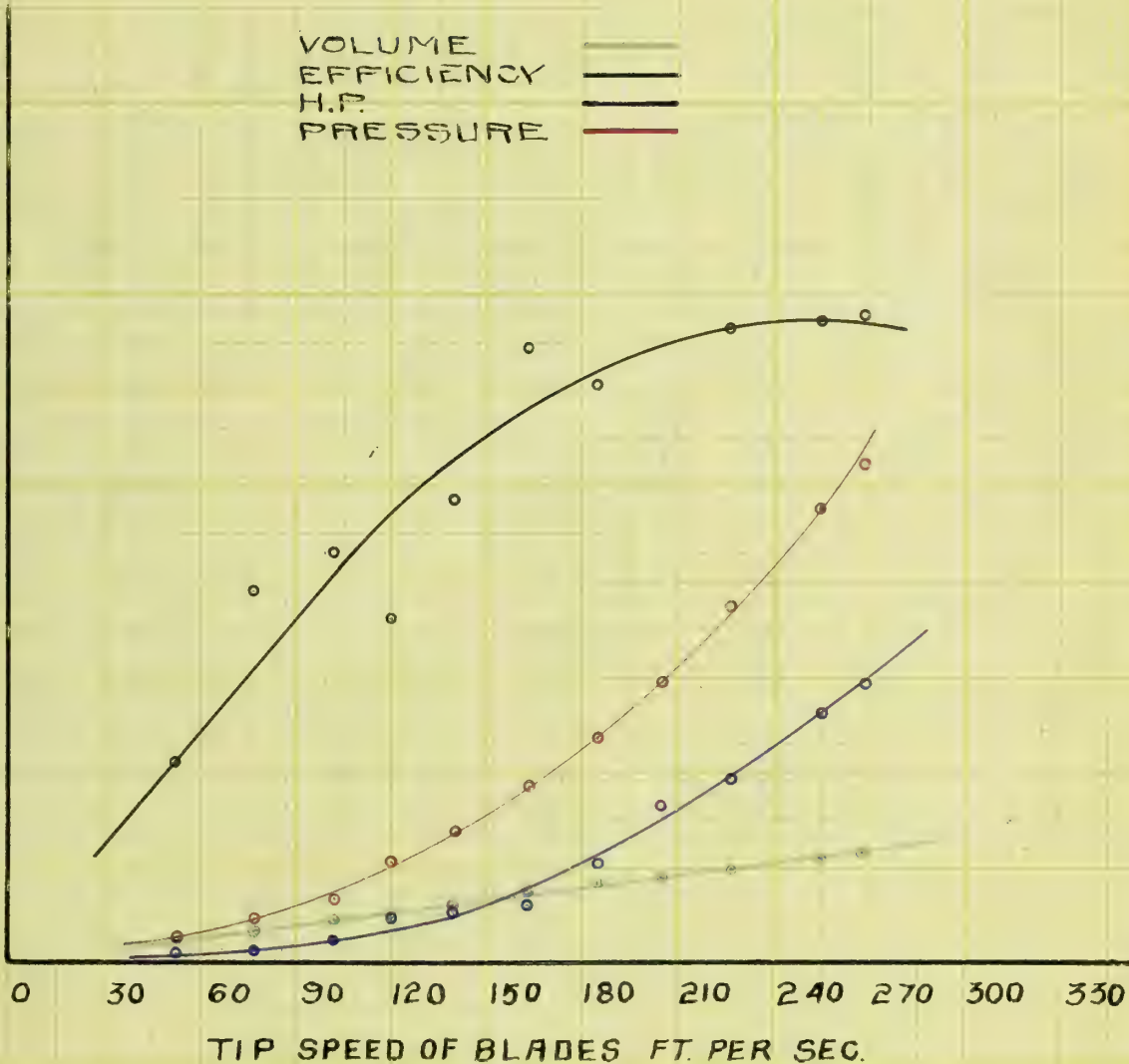
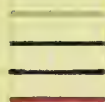


TABLE 15.

DATA AND RESULTS
FOR
BUFFALO BLOWER NO 4.
O OPENING
OF
DISCHARGE

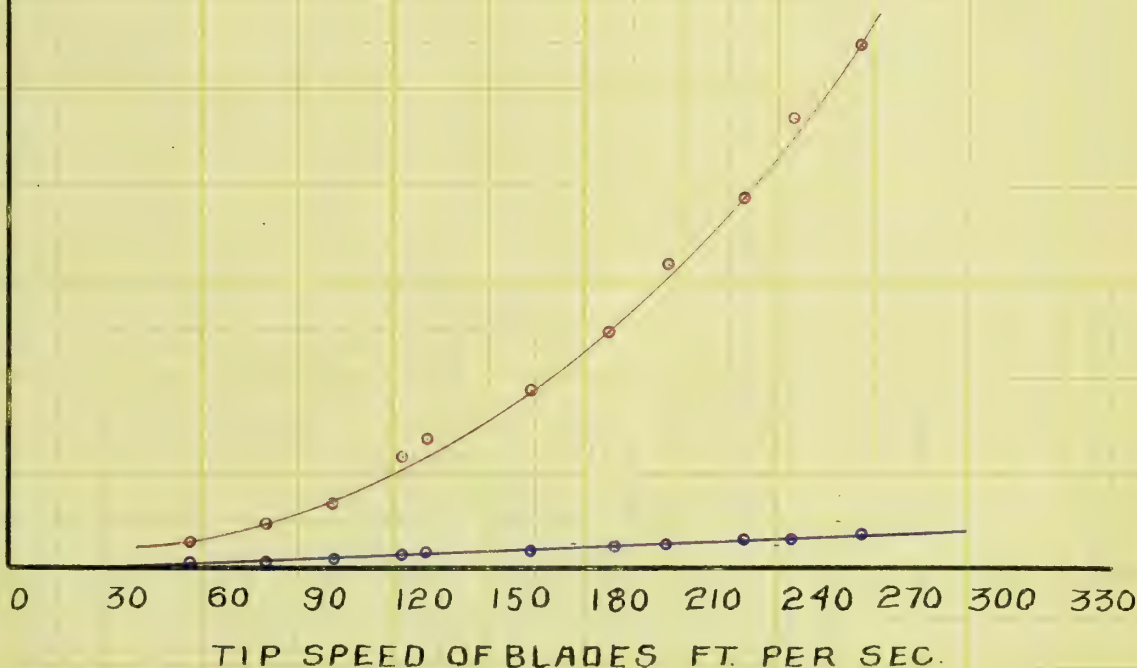
R.P.M. FAN	R.P.M. ENG	PRESSURE OZ. PER. SQ. IN	VEL. HEAD IN WATER	VEL. OF AIR. FT. PER. SEC	AIR DISCH. CU. FT. PER. SEC.	VEL. FAN TIPS FT. PER. SEC.	H.P. TOTAL	H.P. TO DRIVE FAN	H.P. THEORETICAL	CU. FT. AIR DISCH. PER. H.P. PER SEC.	EFF. O/O.
800	50	.53	0	0	0	57	.31	.16	0	0	0
1120	69	.92	0	0	0	80	.57	.23	0	0	0
1418	70	1.37	0	0	0	101	.63	.38	0	0	0
1738	109	2.28	0	0	0	123	1.23	.59	0	0	0
1984	124	2.87	0	0	0	131	1.40	.60	0	0	0
2318	147	3.70	0	0	0	164	1.75	.67	0	0	0
2652	167	4.92	0	0	0	188	2.20	.92	0	0	0
2916	183	6.30	0	0	0	207	2.64	1.00	0	0	0
3244	205	7.70	0	0	0	230	3.19	1.18	0	0	0
3470	220	9.40	0	0	0	246	4.18	1.26	0	0	0
3770	240	10.70	0	0	0	267	4.41	1.34	0	0	0

CHARACTERISTIC CURVES FOR BUFFALO BLOWER TABLE 15.

VOL. CU. FT. PER SEC.
EFFICIENCY
H.P.
OZ. PRESSURE

0	20	40	60	80	100	120	140	160	180	200
0	10	20	30	40	50	60	70	80	90	100
0	4	8	12	16	20	24	28	32	36	40
0	2	4	6	8	10	12	14	16	18	20

VOLUME
EFFICIENCY
H.P.
PRESSURE



EXPERIMENT NO.4

Hand-pump Blower No. 1

See Plate 4, page 81:- This is the smallest size of pressure blower built for the general trade and is suitable for all purposes where a small volume of air at a pressure of from five to ten ounces is desired. Its casing constructed of cast iron has two inlet openings. The blast wheel is constructed ^{almost} entirely of steel sheet-iron, there being twelve blades riveted to conical side plates and the whole carried by, and fastened to the hub by means of steel spokes, in the same way that a bicycle rim is fastened to its hub. The blades are curved from the hub

to the rim of the wheel, in the form of a spiral.

Table of Dimensions:

Height Total		$22\frac{1}{2}"$
Length " "		$23\frac{1}{2}"$
Width " "		$14"$
Diam. of Pulleys		$3"$
Face " " "		$2\frac{3}{8}"$
Diam. " Shaft		$7\frac{1}{16}"$
Width of Blast Wheel	<div> <div>Outer</div> <div>Core.</div> </div>	<div> <div>$1\frac{1}{2}"$</div> <div>$3\frac{1}{2}"$</div> </div>
Diam. " " " " "		$12"$
No. of Blades		18.
Size " " "		$4" \times 1\frac{1}{2}" \times 2\frac{1}{2}"$
Area " " "		8 sq. in.
Diam. of Discharge Opening		$4\frac{1}{4}"$
Area " " " " "		14.18 sq. in.
Diam. of Inlets		$5"$

Area of Inlets (two)

37.77 sq. in.

Ratio $\frac{\text{Inlet area}}{\text{Outlet area}} =$

1.7

Temperature and Barometer Readings

Barometer Height (in)

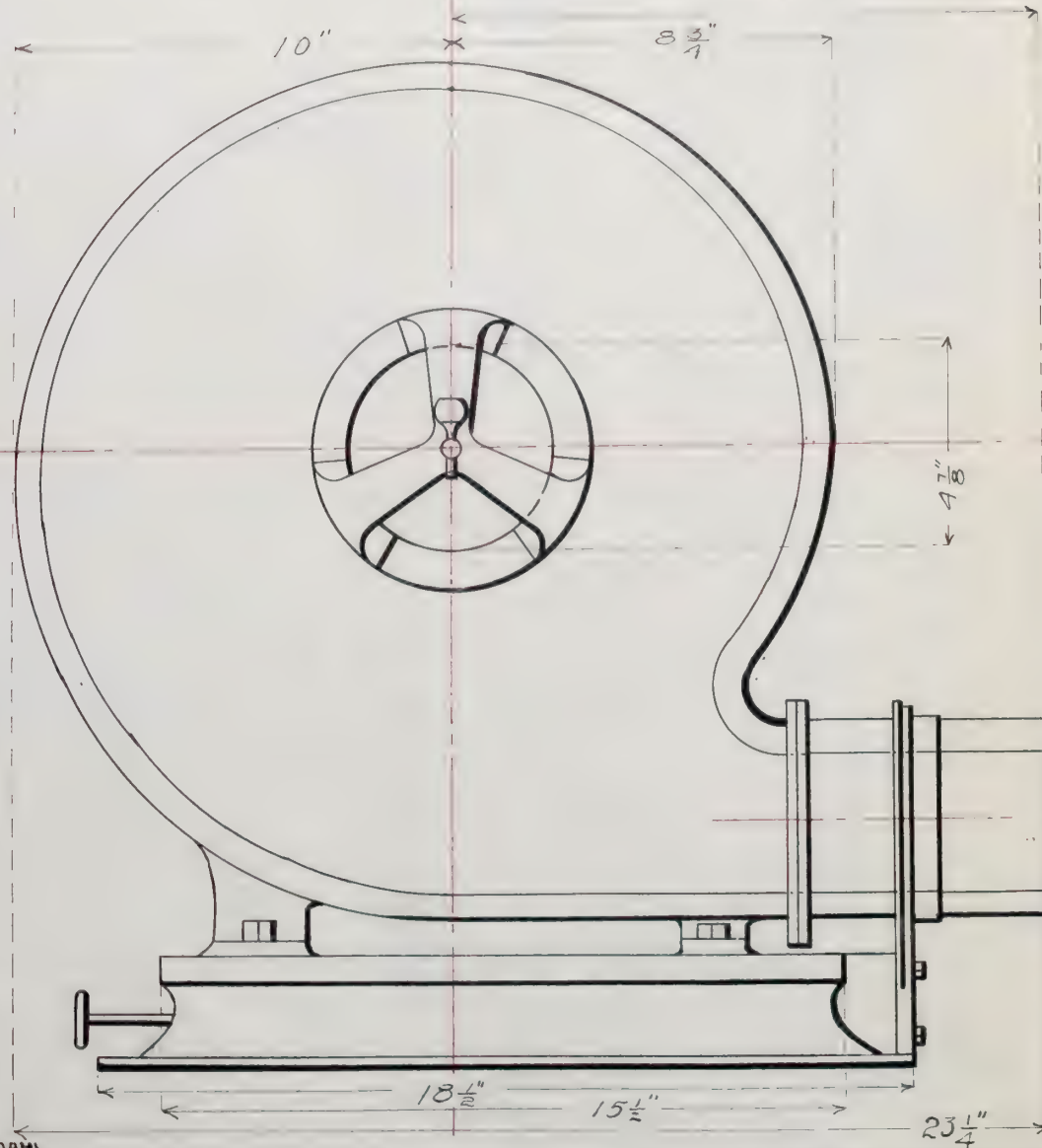
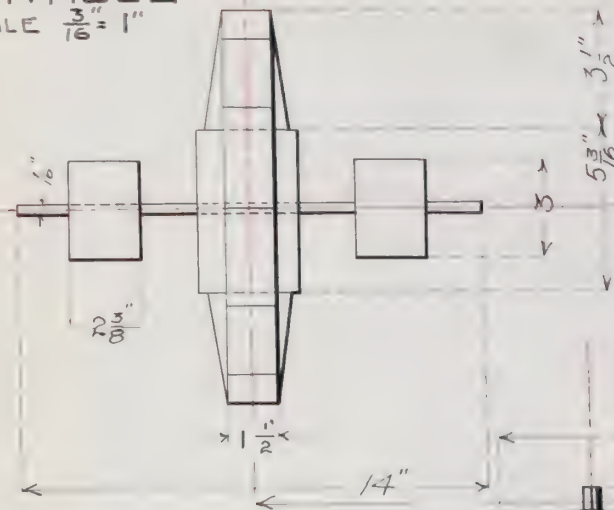
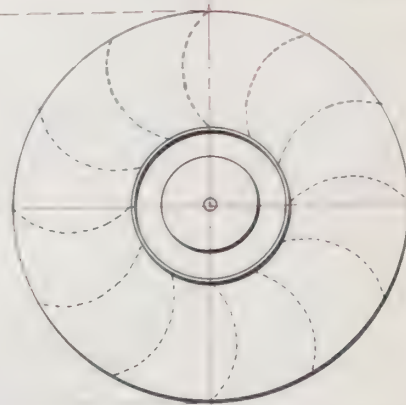
29.9

Temperature (°C)

80°.

PLATE IV.
STURTEVANT BLOWER
NUMBER 1.
WITH
BLAST WHEEL

BLAST WHEEL
SCALE $\frac{3}{16}'' = 1''$



BLOWER
SCALE $\frac{1}{4}'' = 1''$

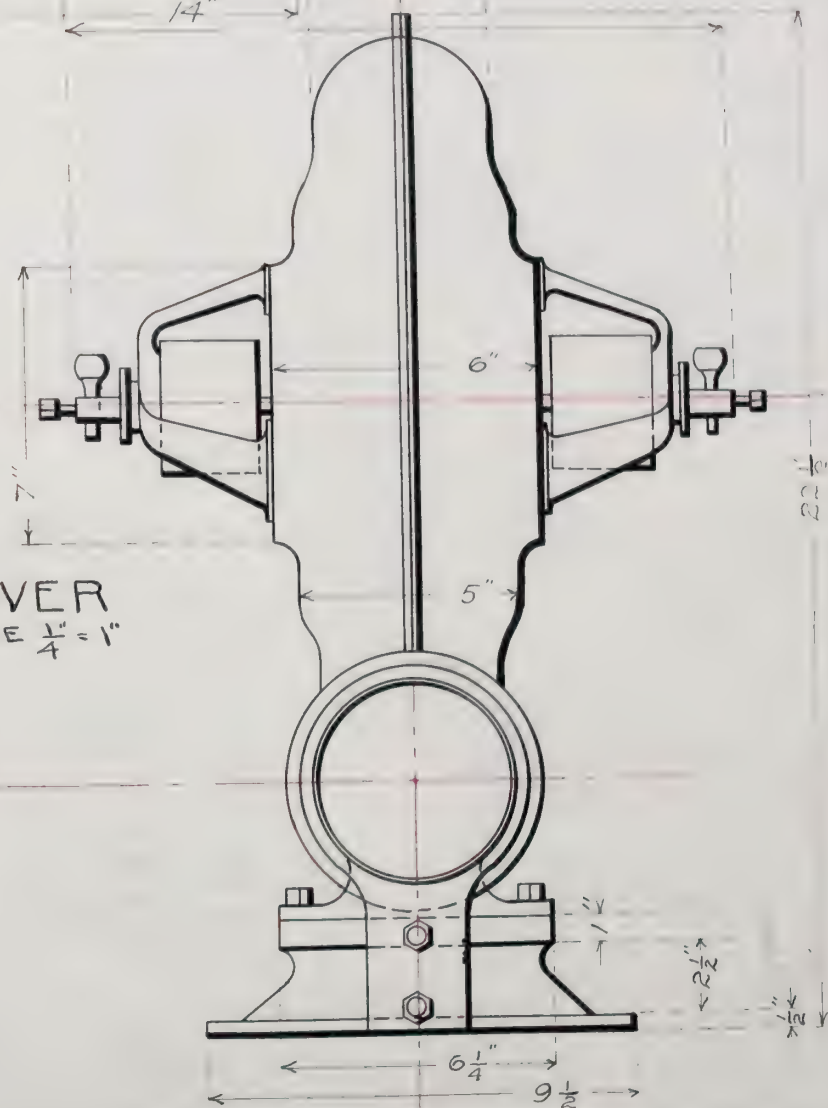


TABLE 16.

DATA AND RESULTS
FOR
STURTEVANT BLOWYER NO 1.
FULL OPENING
OF
DISCHARGE

[illegible]

CHARACTERISTIC CURVES FOR STURTEVANT BLOWER TABLE 16.

VOL. CU. FT. PER SEC.
EFFICIENCY
H.P.
OZ. PRESSURE

200 180 160 140 120 100 80 60 40 20 0
100 90 80 70 60 50 40 30 20 10 0
40 36 32 28 24 20 16 12 8 4 0
20 18 16 14 12 10 8 6 4 2 0

VOLUME
EFFICIENCY
H.P.
PRESSURE

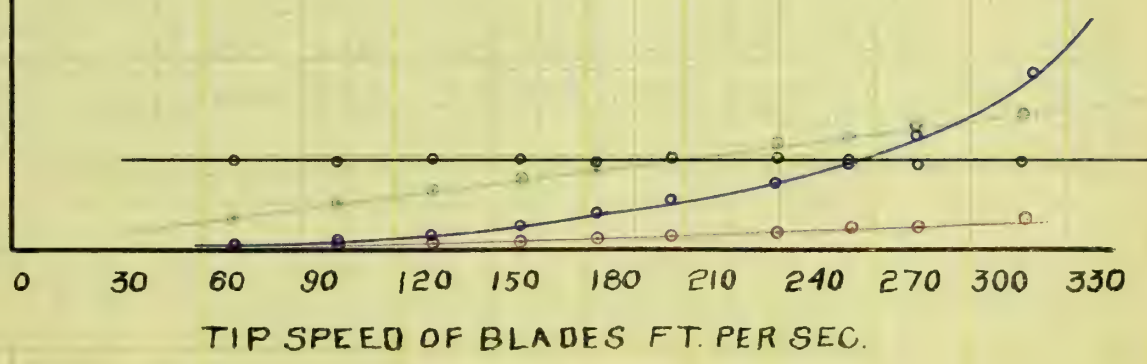


TABLE 17.

DATA AND RESULTS
FOR
STURTEVANT BLOWER NO. 1.
1/3 OPENING
OF
DISCHARGE

[illegible]

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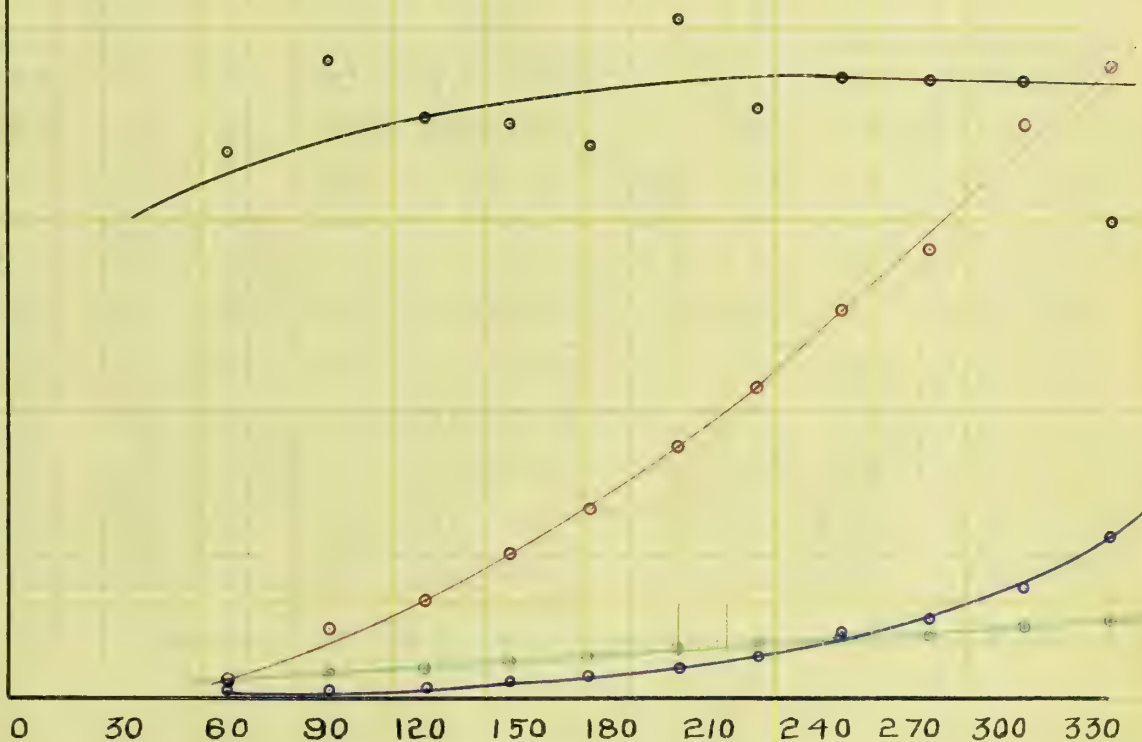
UNIVERSITY OF CHICAGO

CHARACTERISTIC CURVES FOR STURTEVANT BLOWER TABLE 17.

VOL CU. FT. PER SEC.
EFFICIENCY
H.P.
OZ. PRESSURE

200	180	160	140	120	100	80	60	40	20	0
100	90	80	70	60	50	40	30	20	10	0
40	36	32	28	24	20	16	12	8	4	0
20	18	16	14	12	10	8	6	4	2	0

VOLUME
EFFICIENCY
H.P.
PRESSURE



TIP SPEED OF BLADES FT. PER SEC.

TABLE 18.

DATA AND RESULTS
FOR
STURTEVANT BLOWER NO. 1.

$\frac{2}{3}$ OPENING
OF
DISCHARGE

[illegible]

UNIVERSITY OF CHICAGO

1954

CHARACTERISTIC CURVES FOR STURTEVANT BLOWER TABLE 18.

VOL. CU. FT. PER SEC.
EFFICIENCY
H.P.
OZ. PRESSURE

0	20	40	60	80	100	120	140	160	180	200
0	10	20	30	40	50	60	70	80	90	100
0	4	8	12	16	20	24	28	32	36	40
0	2	4	6	8	10	12	14	16	18	20

VOLUME
EFFICIENCY
H.P.
PRESSURE

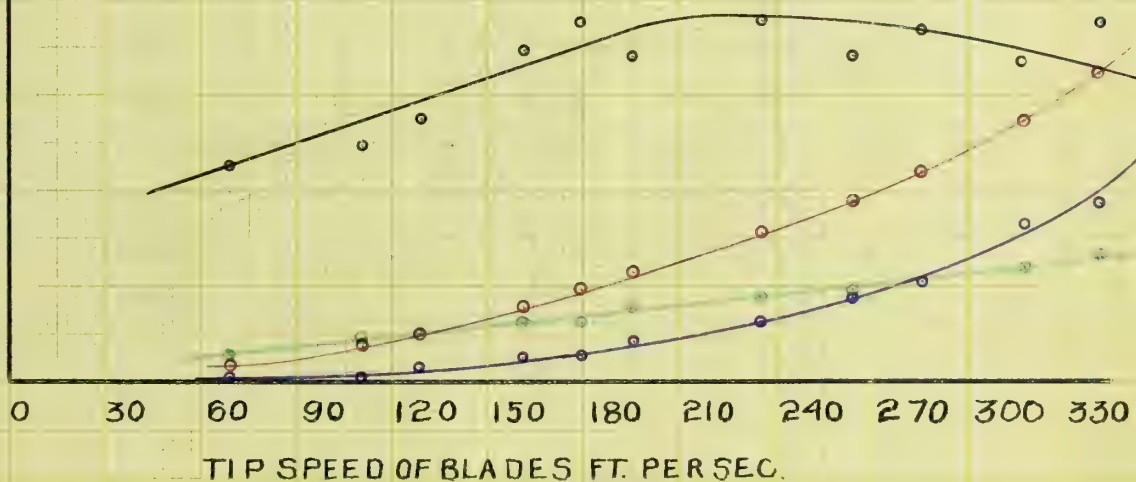


TABLE 19.
DATA AND RESULTS
STURTEVANT BLOWER NO 1.
0 OPENING
OF
DISCHARGE

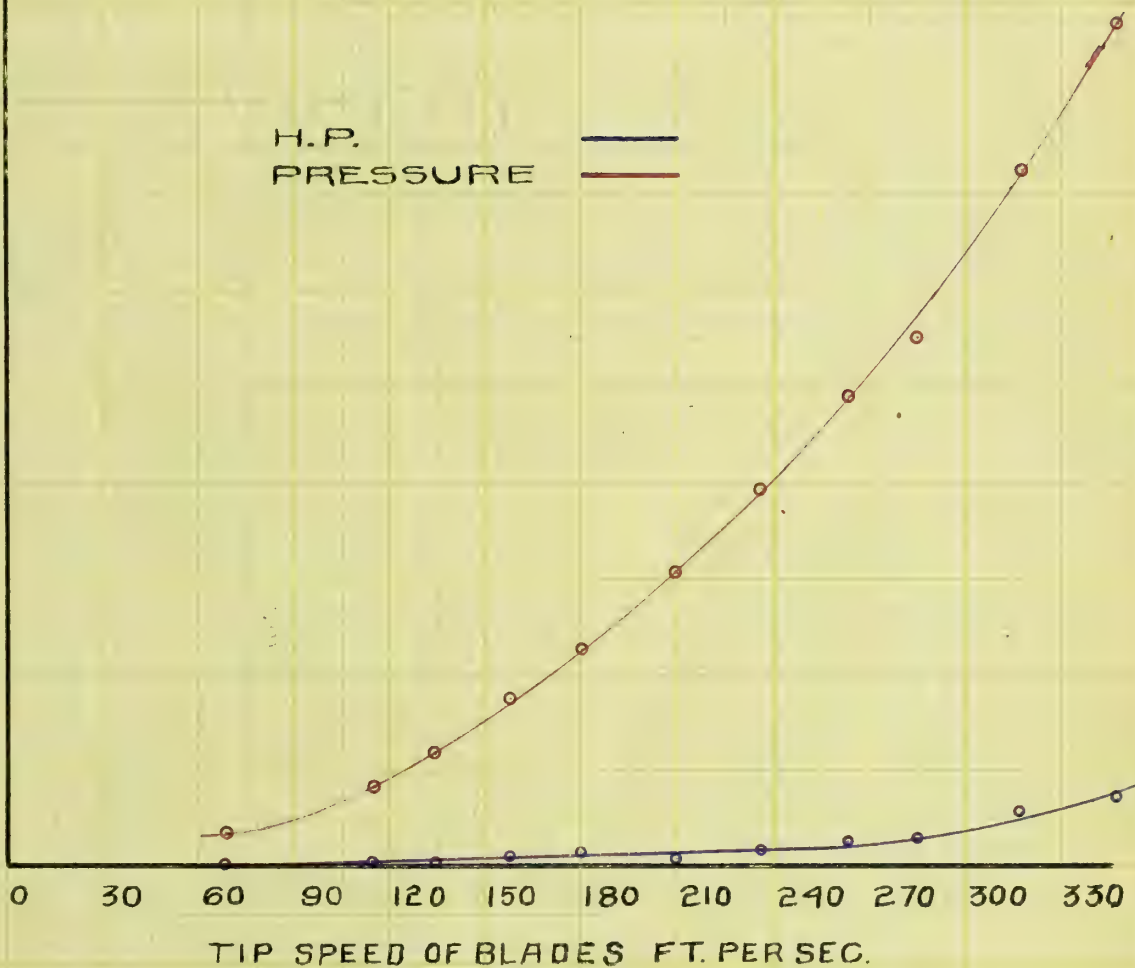
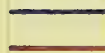
R.P.M. FAN	R.P.M. ENG	PRESSURE OZ. PER SQ. IN.	VEL HEAD IN. WATER	VEL OF AIR FT. PER. SEC.	AIR DISCH. CU. FT. PER SEC.	VEL. FAN TIPS FT. PER SEC.	H.P. TOTAL	H P TO DRIVE FAN	H.P. THEORETICAL	CU. FT. AIR DISCH. PER. H.P. PER SEC.	EFF. O/O
1290	50	.74	0	0	0	68	.28	.03	0	0	0
2162	84	1.69	0	0	0	116	.58	.15	0	0	0
2580	100	2.37	0	0	0	134	.73	.18	0	0	0
3020	118	3.50	0	0	0	158	1.11	.39	0	0	0
3440	134	4.56	0	0	0	181	1.43	.53	0	0	0
4010	156	6.18	0	0	0	210	1.56	.36	0	0	0
4502	175	7.90	0	0	0	236	2.20	.69	0	0	0
5030	196	9.80	0	0	0	263	2.88	.98	0	0	0
5450	212	11.00	0	0	0	285	3.38	1.13	0	0	0
6120	238	14.50	0	0	0	320	5.07	2.22	0	0	0
6650	260	17.50	0	0	0	348	6.20	2.80	0	0	0
7050		19.20				369					

CHARACTERISTIC CURVES FOR STURTEVANT BLOWER TABLE 19.

VOL. CU. FT. PER SEC.
EFFICIENCY
H.P.
OZ. PRESSURE

0	20	40	60	80	100	120	140	160	180	200
0	10	20	30	40	50	60	70	80	90	100
0	4	8	12	16	20	24	28	32	36	40
0	2	4	6	8	10	12	14	16	18	20

H.P.
PRESSURE



EXPERIMENT NO. 5

35" Buffalo Exhauster.

(See Plate 1, p. 94.) This Buffalo Steel Plate Blowing Mill Exhauster was constructed of heavy steel plate firmly braced and stiffened with angle iron, &c. heavy cast iron pedestal, entirely independent of the fan shell, carried the pulley wheel and ring oiling bearings. The exhauster (like all exhausters) had a single inlet orifice and an overhanging blast wheel. The latter consisted essentially of a cast iron hub with wrought iron spider arms, conical side plates and steel blades, the tips of which were slightly curved backward.

Table of Dimensions.

Height Total		37 $\frac{3}{4}$ "
Length " "		36 $\frac{1}{4}$ "
Width " "		41 $\frac{3}{8}$ "
Diam. of Pulley		8"
Face " " "		7"
Diam. of Shaft		1 $\frac{3}{4}$ "
Length of Bearings		6 $\frac{3}{8}$ and 7 $\frac{5}{8}$ "
Diam. of Blast Wheel at	{ Center	12 $\frac{3}{4}$ "
	{ Circ.	9 $\frac{1}{2}$ "
No. of Blades.		5
Area " " "		86.6 sq. in.
Size of Discharge Opening	{ Outside of Flange	13 $\frac{3}{8}$ " x 13 $\frac{1}{2}$ "
	{ Inside " " "	15" x 13"
Area " " " "	{ Outside of Flange	150 sq. in.
	{ Inside of Flange	169 sq. in.
Diam. of Inlet	{ Outside of Flange	14 $\frac{5}{8}$ "
	{ Inside " " "	14 $\frac{1}{4}$ "

Area of Inlet { Outside of Flange 167.927 in.
 Inside " " " 154.5 sq. in.

$$\text{Ratio } \frac{\text{Inlet Area}}{\text{Outlet Area}} = .94$$

Temperature and Barometer Readings.

Barometer Height Av. 29.99 "

Temperature Av. 92.5° F.



PLATE V.

40" BUFFALO EXHAUSTER

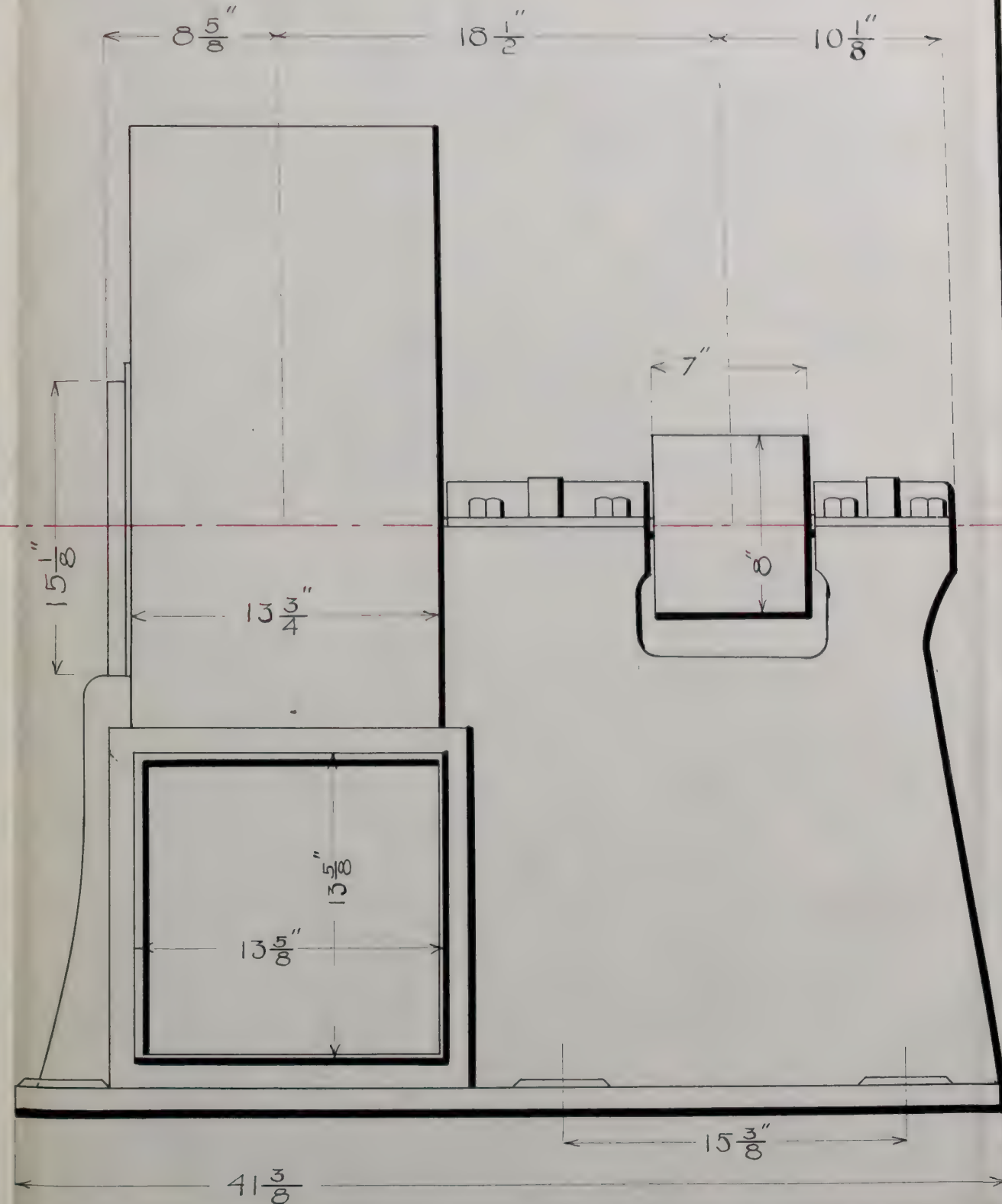
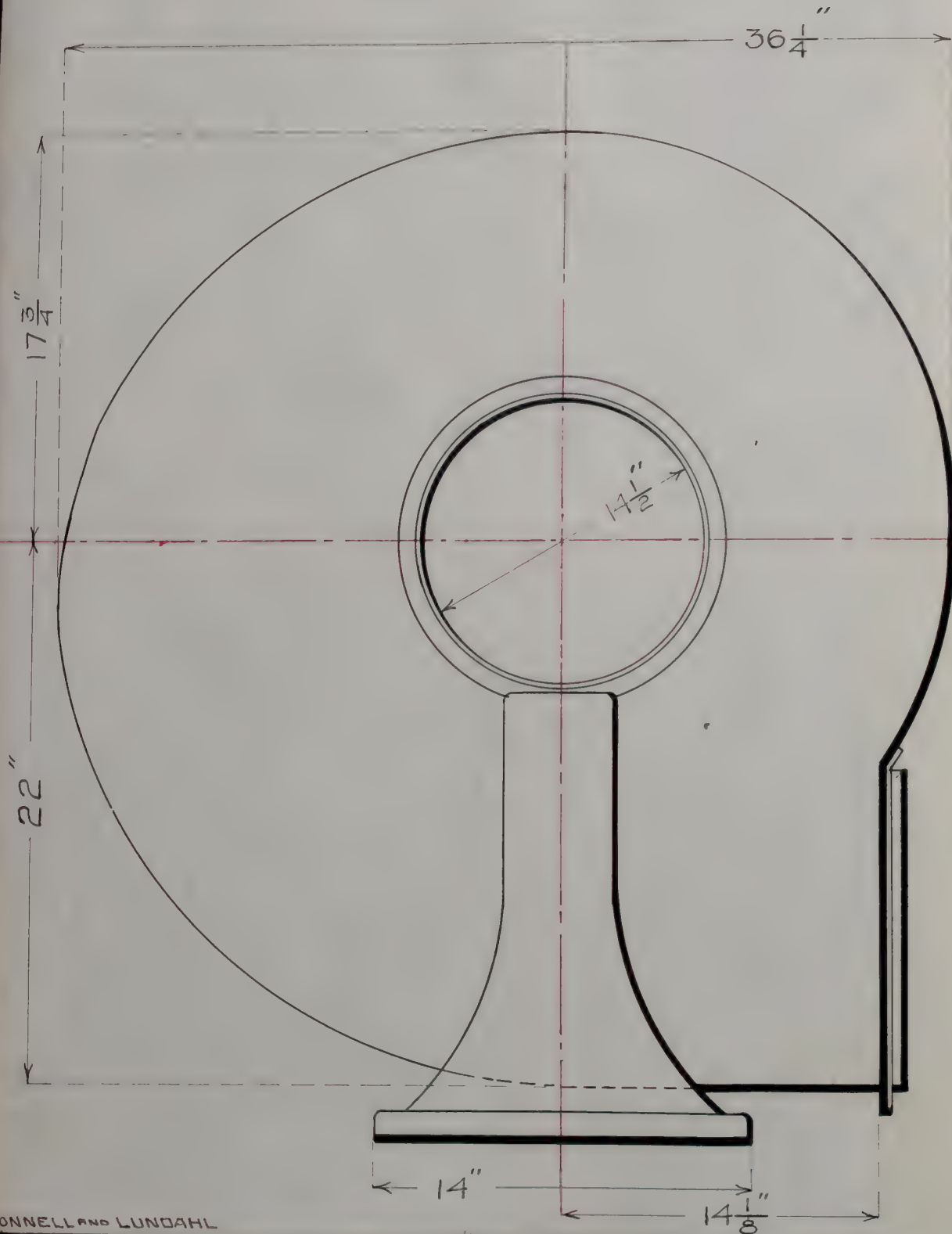
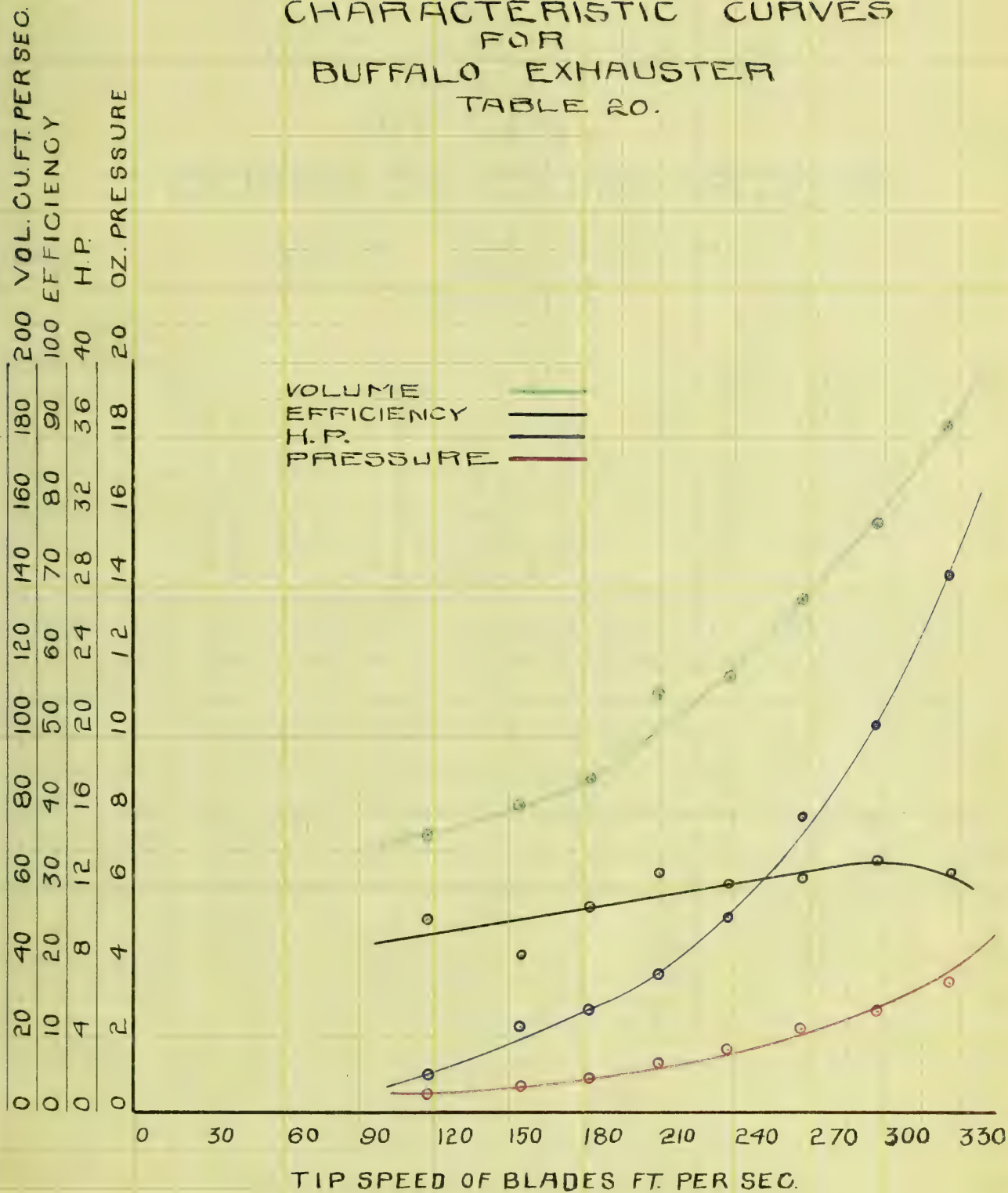


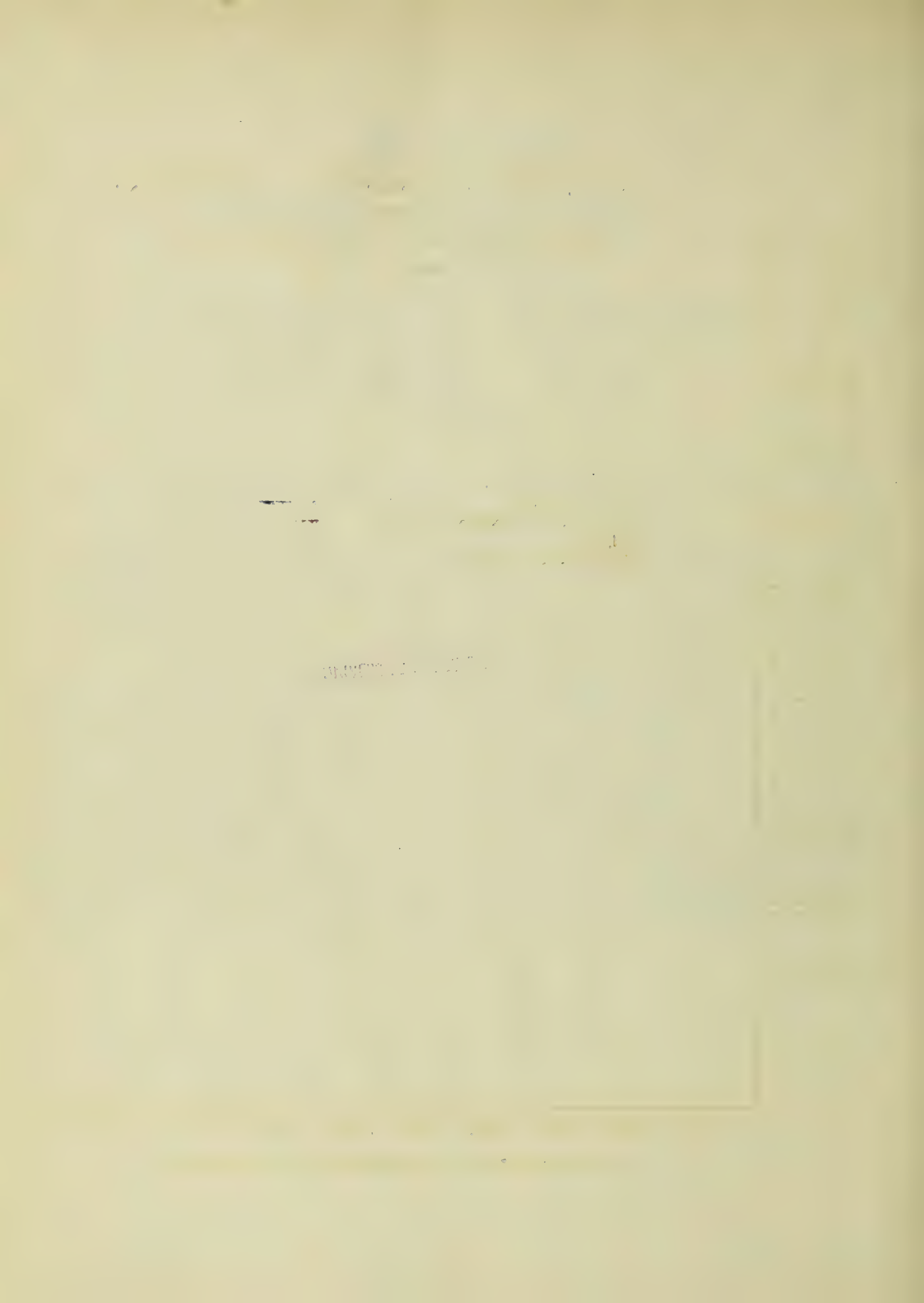
TABLE 20.

DATA AND RESULTS
FOR
40" INCH
BUFFALO EXHAUSTER
FULL OPENING
OF
INTAKE

[illegible]

CHARACTERISTIC CURVES FOR BUFFALO EXHAUSTER TABLE 20.

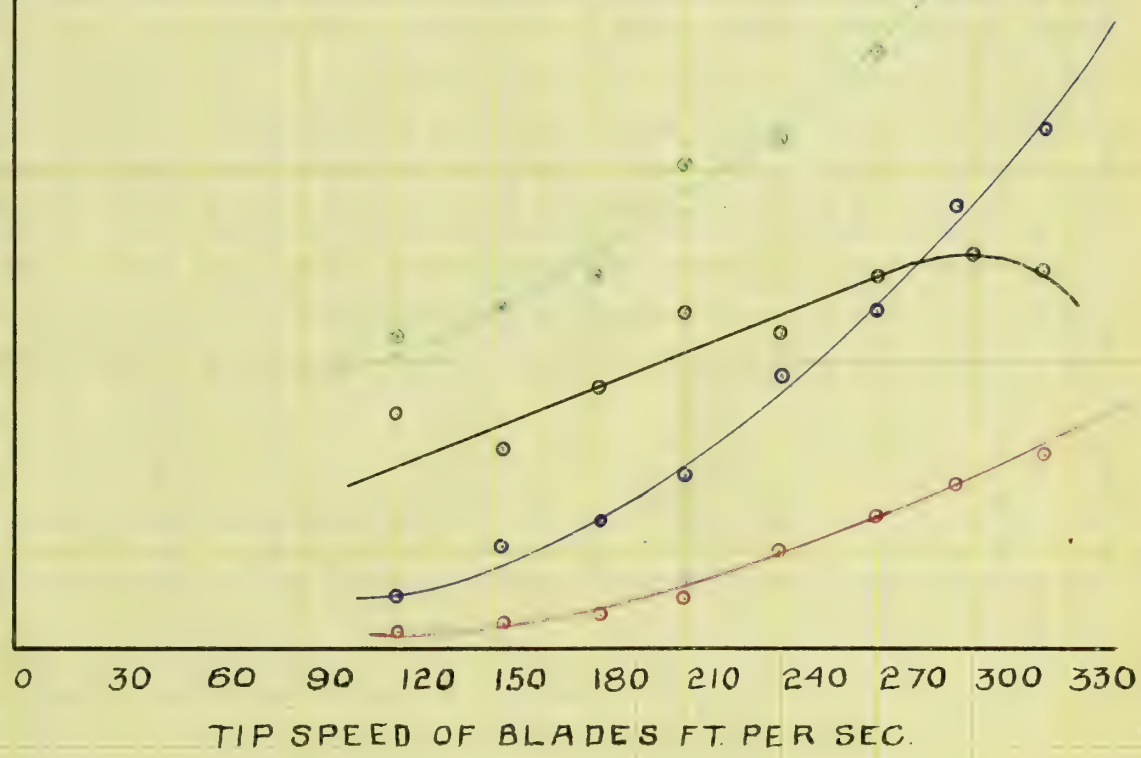




CHARACTERISTIC CURVES FOR BUFFALO EXHAUSTER TABLE 21.

VOL. CU. FT. PER SEC.		EFFICIENCY		H.P.		OZ. PRESSURE	
0	20	0	4	0	2	0	2
0	40	0	8	0	4	0	4
0	60	0	12	0	6	0	6
0	80	0	16	0	8	0	8
0	100	0	20	0	10	0	10
0	120	0	24	0	12	0	12
0	140	0	28	0	14	0	14
0	160	0	32	0	16	0	16
0	180	0	36	0	18	0	18
0	200	0	40	0	20	0	20

VOLUME
EFFICIENCY
H.P.
PRESSURE

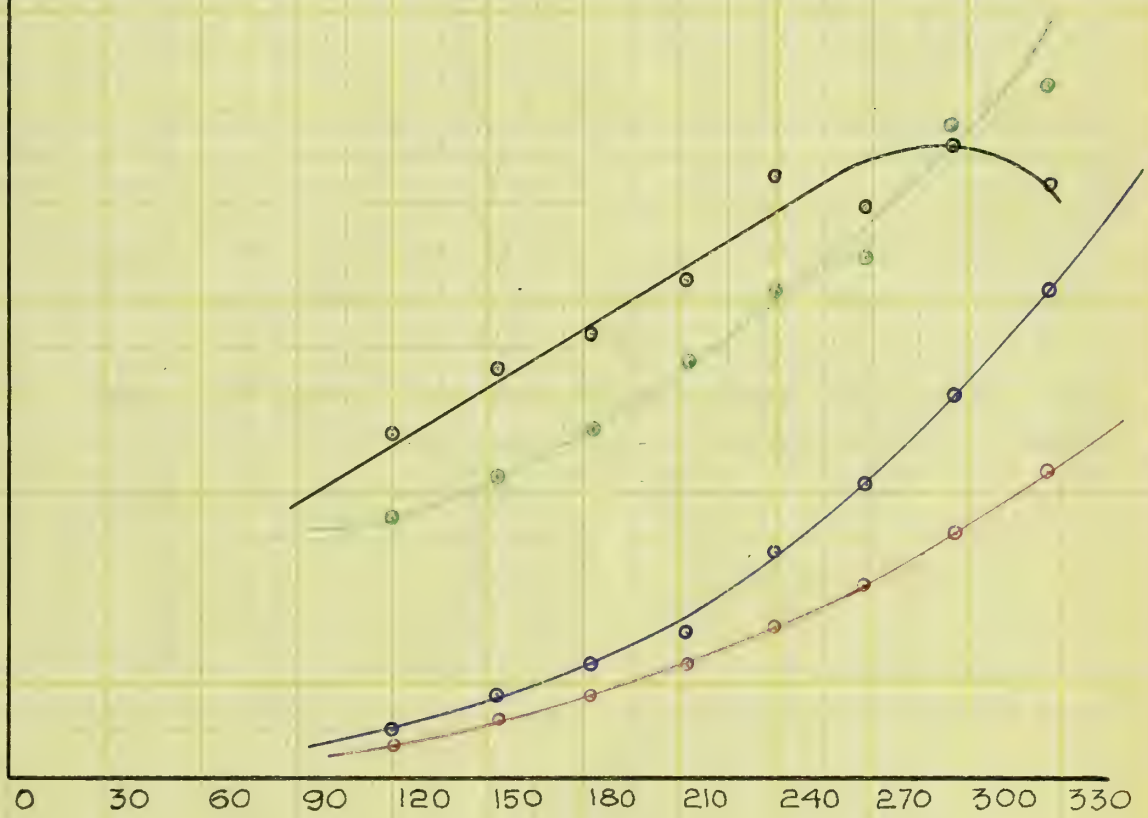


CHARACTERISTIC CURVES FOR BUFFALO EXHAUSTER TABLE 22.

VOL. CU. FT. PER. SEC.
EFFICIENCY
H.P.
OZ. PRESSURE

200	180	160	140	120	100	80	60	40	20	0
100	90	80	70	60	50	40	30	20	10	0
40	36	32	28	24	20	16	12	8	4	0
20	18	16	14	12	10	8	6	4	2	0

VOLUME
EFFICIENCY
H.P.
PRESSURE



TIP SPEED OF BLADES FT. PER SEC.

TABLE 23.

DATA AND RESULTS
FOR
40" INCH
BUFFALO EXHAUSTER
1/4 OPENING
OF
INTAKE

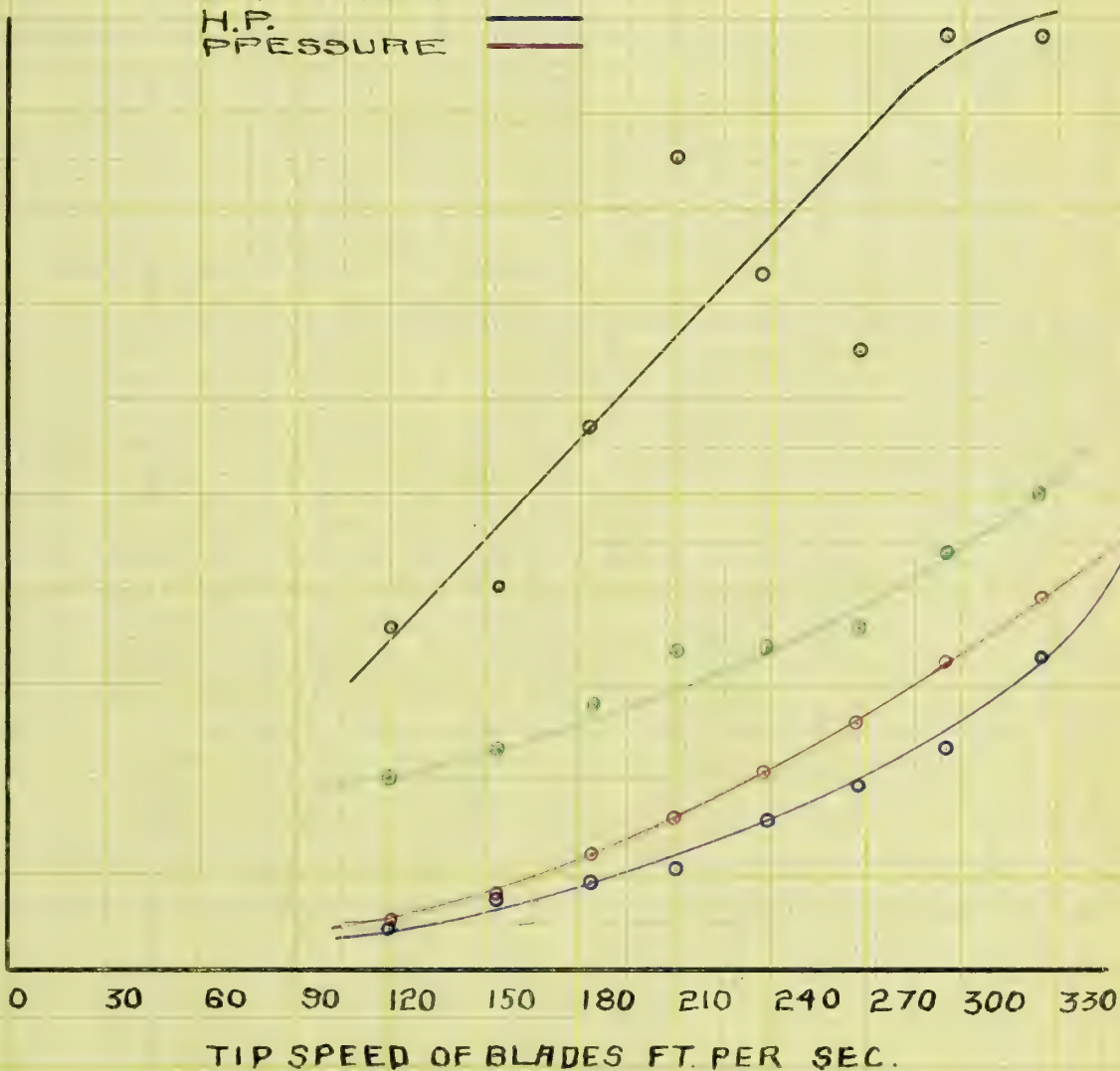
[illegible]

CHARACTERISTIC CURVES FOR BUFFALO EXHAUSTER TABLE 23

VOL. CU. FT. PER SEC
EFFICIENCY
H.P.
OZ. PRESSURE

0	20	40	60	80	100	120	140	160	180	200
0	10	20	30	40	50	60	70	80	90	100
0	4	8	12	16	20	24	28	32	36	40
0	2	4	6	8	10	12	14	16	18	20

VOLUME
EFFICIENCY
H.P.
PRESSURE



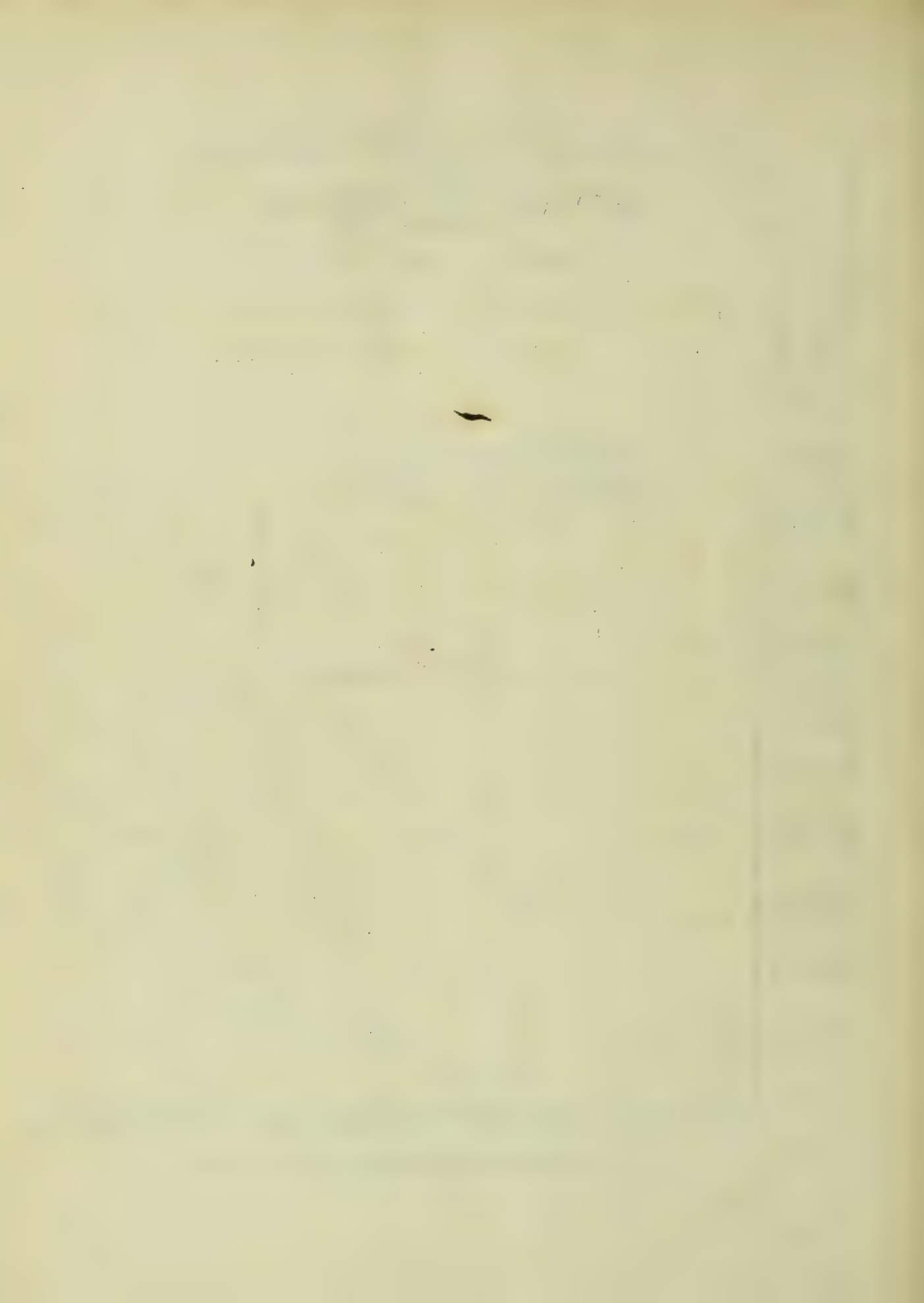


TABLE 24.

DATA AND RESULTS
FOR
40 INCH
BUFFALO EXHAUSTER
O OPENING
OF
INTAKE

[illegible]

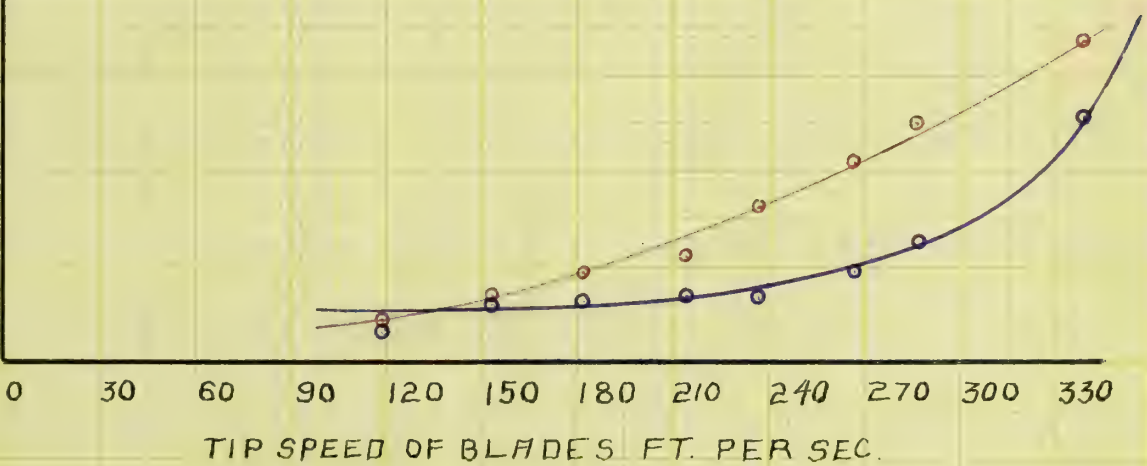
CHARACTERISTIC CURVES FOR BUFFALO EXHAUSTER TABLE 24

VOL. CU. FT. PER SEC
EFFICIENCY
H.P.
OZ. PRESSURE

0	20	40	60	80	100	120	140	160	180	200
0	10	20	30	40	50	60	70	80	90	100
0	4	8	12	16	20	24	28	32	36	40
0	2	4	6	8	10	12	14	16	18	20

VOLUME
EFFICIENCY
H.P.
PRESSURE

==



Results.

Tables and Curves:— The results of each experiment are included in a series of five tables, with the exception of the Sturtevant Blower No. 1, which has only four, because it had only four openings or conditions of its discharge.

Characteristic curves, for each table of results, are plotted on the page following the table, for each fan.

Discussion of Results:—

Power Required by the Fan.— By study of the results, it will be found that the maximum power consumed is for the full discharge opening, when the pressure is the lowest, and that the pressure consumed varies

approximately as the square of the speed for each discharge opening. With a closed gate the power necessary to drive the fan is very small, notwithstanding the fact that the pressure is the highest. This is because there is no air passing through the fan.

(Pressure:— The pressure is the lowest at the full discharge opening and becomes a maximum at the zero opening.

However, for three fourths gate opening the pressure recorded was very often as high as for a closed gate. For quarter opening of the discharge the pressure does not increase so fast in relation to the speed,

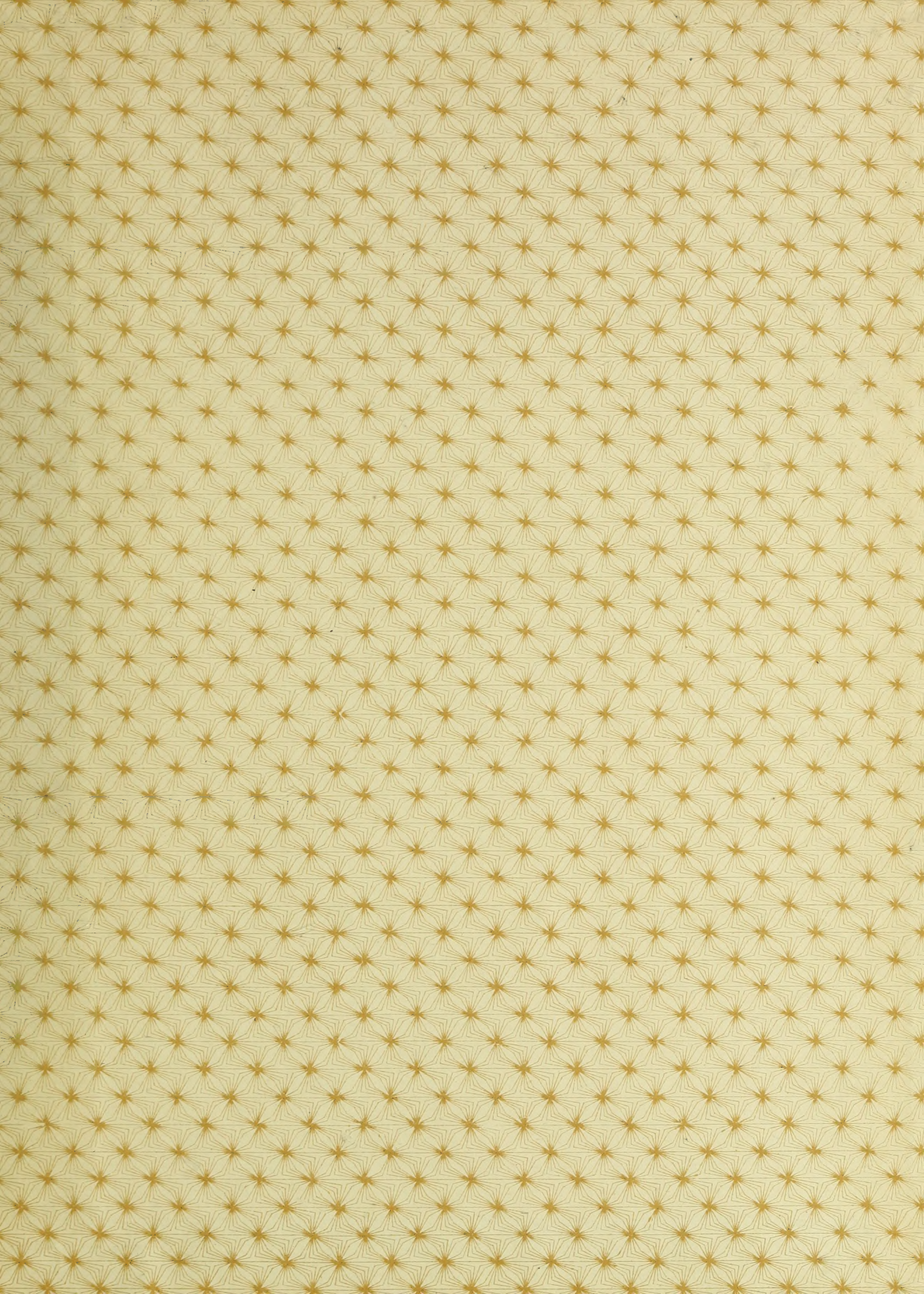
as did the H.P. required to drive the fan, while for half opening of the discharge their ratios of increase were about equal. With the three quarter and closed discharge the pressure increased about as the cube of the speed.

Velocity: In all cases the velocity increased about as the cube of the speed.

Efficiency:— The efficiency is always the lowest for the full gate opening, where the discharge is a maximum. This is due to the fact that the air is discharged at a very low pressure as compared to the other gate openings. The

efficiency increases approximately, directly as the speed and as the size of the discharge opening decreases, up to a certain point, which varies in different fans, and then falls quickly to zero, as the gate is closed.





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